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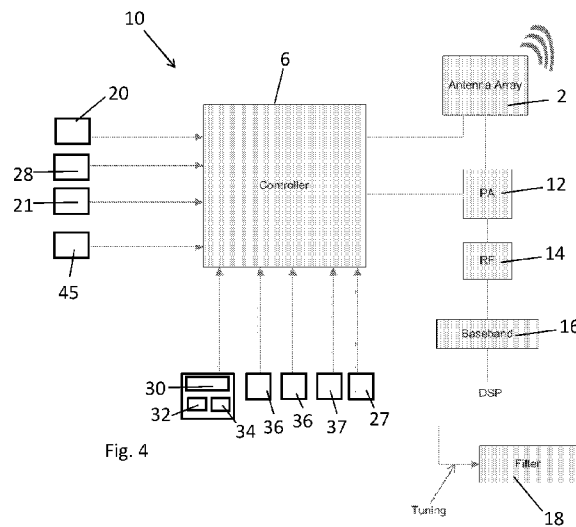
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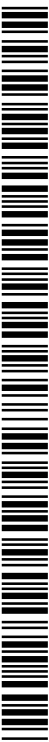
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(54) Title: METHOD AND STEERABLE ANTENNA APPARATUS



(57) Abstract: The invention provides a method of adjusting a principal communication direction of a steerable directional antenna for communicating with a terrestrial electromagnetic signal source, the method comprising: providing location specific steering data comprising one or more steering data portions, each of the steering data portions being specific to a respective location; determining a location of the steerable directional antenna; selecting a steering data portion from the location specific steering data taking into account the determined location of the antenna; determining an adjusted principal communication direction of the steerable directional antenna taking into account the said selected steering data portion; and adjusting the principal communication direction of the steerable directional antenna in accordance with the said adjusted principal communication direction.



1 METHOD AND STEERABLE ANTENNA APPARATUS

2

3 Field of the invention

4

5 The invention relates to: a method of adjusting a principal communication direction of
6 a steerable directional antenna for communicating with a terrestrial electromagnetic
7 signal source; steerable directional antenna apparatus; and a method of generating
8 location specific steering data for a steerable directional antenna.

9

10 Background to the invention

11

12 Mobile communications devices use antennas for radio frequency wireless
13 communication with terrestrial electromagnetic signal sources, such as cellular
14 network base stations, Wi-fi access points and Bluetooth beacons. The strengths of
15 signals received by the antennas from such electromagnetic signal sources vary
16 greatly in dependence on the spatial relationship between the mobile device and the
17 signal source. The received signal strength is typically a function of distance and
18 direction of the mobile device from the electromagnetic signal source, but the function
19 can be more complex when obstructions are provided in the line of sight between the
20 mobile device and the electromagnetic signal source, and when multi-path
21 propagation occurs, for example due to signal reflections.

22

23 In order to reduce interference, and therefore improve transmission and reception of
24 electromagnetic signals by the antennas, it is known to provide a directional antenna

1 and to steer the antenna in the direction of the electromagnetic signal source.
2 However, when mobile devices move, the antenna often needs to be steered back
3 towards the electromagnetic signal source to maintain a wireless communications
4 link of the required quality. This can require the antenna to perform a scan by
5 (electronically or mechanically) steering the principal communication direction of the
6 antenna across a range of directions in order to determine an optimum principal
7 communication direction along which to communicate with the electromagnetic signal
8 source, particularly when the antenna is not initially in communication with the
9 electromagnetic signal source (which may require the scan to be performed over a
10 larger range). This scanning process typically takes time and uses a significant
11 quantity of battery power.

12

13 Accordingly a new way of steering steerable directional antennas, which reduces the
14 battery power consumption, is required.

15

16 Summary of the invention

17

18 A first aspect of the invention provides a method of adjusting a principal
19 communication direction of a steerable directional antenna for communicating with a
20 terrestrial electromagnetic signal source, the method comprising: providing location
21 specific steering data comprising one or more steering data portions, each of the
22 steering data portions being specific to a respective (typically absolute) location;
23 determining a location of the steerable directional antenna; selecting a steering data
24 portion from the location specific steering data taking into account the determined
25 location of the antenna (e.g. a steering data portion associated with the determined
26 location); determining an adjusted principal communication direction of the steerable
27 directional antenna taking into account the said selected steering data portion; and
28 adjusting the principal communication direction of the steerable directional antenna in
29 accordance with the said adjusted principal communication direction.

30

31 A second aspect of the invention provides steerable directional antenna apparatus
32 comprising: a steerable directional antenna for communicating with a terrestrial
33 electromagnetic signal source; a memory comprising location specific steering data
34 comprising one or more steering data portions, each steering data portion being
35 specific to a respective location; and a controller comprising one or more computer
36 processors, the controller being configured to: determine (e.g. receive) a location of
37 the steerable directional antenna; select a steering data portion from the location

1 specific steering data taking into account the determined location of the antenna (e.g.
2 a steering data portion associated with the determined location); determine an
3 adjusted principal communication direction of the steerable directional antenna taking
4 into account the said selected steering data portion; and adjust the principal
5 communication direction of the steerable directional antenna in accordance with the
6 said adjusted principal communication direction.

7

8 It will be understood that the controller of the second aspect of the invention may be
9 configured to perform any steps of the method of the first aspect of the invention.

10

11 The selected steering data portion is typically specific to the determined location of
12 the antenna. In other cases, the selected steering data portion is specific to a future
13 location of the antenna predicted taking into account the said determined location of
14 the antenna.

15

16 A change in the location of the antenna affects the direction of the (typically fixed
17 position) terrestrial electromagnetic signal source relative to the antenna. The
18 location of the antenna also affects the signal propagation path (and therefore the
19 signal attenuation and signal reflections incurred over the signal propagation path)
20 taken by electromagnetic signals between the antenna and the terrestrial
21 electromagnetic signal source. By selecting a steering data portion taking into
22 account the determined location of the antenna and adjusting the principal
23 communication direction of the steerable directional antenna taking into account the
24 said selected steering data portion, the antenna can be brought into communication
25 with the electromagnetic signal source (or the quality of the communications link
26 between the antenna and the electromagnetic signal source can be improved)
27 without having to perform a full scan of detectable electromagnetic signal sources
28 when the antenna changes location (thereby saving processing and battery power).
29 In addition, the steerable directional antenna can be steered towards a preferred
30 communication direction for communicating with the terrestrial electromagnetic signal
31 source much more quickly than if a full scan of detectable electromagnetic signal
32 sources was required. This also helps to reduce the quantity of signal processing
33 required thereby reducing electrical power consumption.

34

35 It may be that one or more or each of the steering data portions comprises data from
36 which the adjusted principal communication direction of the antenna can be
37 determined. For example, it may be that the said steering data portions comprise the

1 locations (e.g. a map) of one or more terrestrial (typically RF) electromagnetic signal
2 sources with which the antenna can communicate (e.g. from the location with which
3 the said steering data portion is associated). Typically the said electromagnetic
4 signal sources include the said terrestrial electromagnetic signal source. It may be
5 that the method comprises: determining the adjusted principal communication
6 direction of the antenna taking into account the location of the terrestrial
7 electromagnetic signal source obtained from the selected steering data portion.

8

9 It may be that one or more or each of the said steering data portions comprises
10 configuration data for adjusting the principal communication direction of the antenna,
11 the said configuration data being specific to a location with which the said steering
12 data portion is associated. For example, the configuration data may comprise
13 (individually selectable) beamforming phase shift coefficients and/or weightings to be
14 applied to signals transmitted from or received by each of a plurality of antenna
15 elements of the antenna. Alternatively the configuration data may identify sectors of
16 a sector antenna to be activated (and optionally deactivated). Alternatively the
17 configuration data may identify a rotational orientation of a mechanically rotatable
18 antenna. In this case, the step of determining the adjusted principal communication
19 direction comprises receiving said configuration data, typically specific to a current or
20 predicted future location of the antenna. The said configuration data may then be
21 adapted if necessary taking into account one or more additional parameters (e.g.
22 orientation, usage mode, sensor signals - see below) before being applied to the
23 antenna.

24

25 It may be that the locations to which the respective steering data portions are specific
26 are points or loci of points in space. The said points or loci may be represented, for
27 example, by (two-dimensional or three-dimensional) location co-ordinates (e.g.
28 longitude, latitude and, for three dimensional co-ordinates, altitude) or one or more
29 ranges of (two-dimensional or three-dimensional) location co-ordinates.

30

31 It may be that one or more or each of the steering data portions is specific to a user of
32 a device comprising the antenna.

33

34 Typically one or more or each of the steering data portions are derived from prior
35 activity of a user (typically at each of the said respective locations).

36

1 It may be that one or more or each of the steering data portions are derived from prior
2 usage of the antenna by a user (typically at each of the said respective locations).

3

4 It may be that the said location specific steering data is provided in a user profile
5 (typically stored on the said memory) which is customised for the user.

6

7 Typically the method comprises dynamically updating (or the controller is configured
8 to dynamically update) the location specific steering data (e.g. using the method
9 according to the third aspect of the invention or the apparatus according to the fourth
10 aspect of the invention) using steering data derived from activity of the user (e.g.
11 usage of the antenna by the user).

12

13 Typically the controller is configured to obtain data from the user profile stored on the
14 said memory. Typically the controller is configured to dynamically update the user
15 profile stored on the said memory using steering data specific to each of one or more
16 locations derived from activity of the user (e.g. (ongoing) usage of the antenna by the
17 user).

18

19 It may be that the method further comprises selecting (or the controller is configured
20 to select) a said steering data portion from the location specific steering data and/or
21 determining (or the controller is configured to determine) the said adjusted principal
22 communication direction of the steerable directional antenna taking into account
23 sensor data from one or more sensors (typically from one or more sensors of a or the
24 device comprising the antenna).

25

26 It may be that the steerable antenna apparatus further comprises said one or more
27 sensors. It may be that the controller is configured to receive sensor data from the
28 said one or more sensors.

29

30 It may be that one or more or each of the steering data portions is associated with
31 one or more sensor conditions. It may be that the method comprises determining (or
32 the controller is configured to determine) whether the one or more sensor conditions
33 are met by processing the said sensor data and selecting (or the controller is
34 configured to select) a said steering data portion associated with the said sensor
35 conditions, responsive to a determination that the said sensor conditions are met.

36

1 Alternatively, it may be that the method comprises processing (or the controller is
2 configured to process) the selected steering data portion together with the sensor
3 data to determine the said adjusted principal communication direction of the steerable
4 directional antenna.

5

6 The sensors may comprise any one or more (typically any two or more or each) of the
7 following: orientation sensor configured to determine the orientation of the antenna;
8 proximity sensor configured to determine proximity of one or more external objects to
9 the antenna (or to determine whether one or more external objects are in close
10 proximity to the antenna); temperature sensor configured to determine a temperature
11 of an external surface of a housing of a device comprising the antenna; a pressure
12 sensor configured to determine a physical pressure exerted on an external surface of
13 a housing of a device comprising the antenna; headphone sensor configured to
14 determine whether headphones are coupled to a headphone port of the device
15 comprising the antenna; and a usage mode sensor configured to determine a usage
16 mode of the device comprising the antenna.

17

18 The sensors may be implemented in software (e.g. a usage mode sensor may be a
19 signal from an operating system running on the device indicating whether the device
20 is being used to make a call), in hardware (e.g. a pressure sensor may be provided
21 on the housing of the device) or in a combination of hardware and software.

22

23 It will be understood that the orientation of the antenna also affects the direction of
24 the terrestrial electromagnetic signal source relative to the antenna. Accordingly, by
25 taking into account the orientation of the antenna, more accurate steering data can be
26 selected from the location specific steering data.

27

28 It may be that the method further comprises: determining (or the controller is
29 configured to determine) an orientation of the antenna (e.g. pitch and/or yaw and/or
30 roll of the antenna); and selecting (or the controller is configured to select) the said
31 selected steering data portion from the location specific steering data taking into
32 account (e.g. associated with) the determined orientation of the antenna (e.g. relative
33 to the electromagnetic signal source).

34

35 It may be that the method comprises determining (or the controller is configured to
36 determine) an orientation of the antenna relative to the said terrestrial
37 electromagnetic signal source and selecting (or the controller is configured to select)

1 the said steering data portion from the location specific steering data taking into
2 account the determined orientation of the antenna relative to the electromagnetic
3 signal source.

4

5 It may be that one or more or each of the steering data portions is associated with a
6 respective orientation (e.g. with a particular pitch, yaw and roll) of the antenna. It may
7 be that the said selected steering data portion is associated with the determined
8 orientation of the antenna.

9

10 Typically the step of determining an orientation of the antenna comprises determining
11 (or the controller is configured to determine) the orientation of the antenna from
12 sensor data provided by one or more orientation sensors configured to measure the
13 orientation of the antenna. For example, it may be that the method comprises
14 measuring (or the controller is configured to measure) the orientation of the antenna
15 using sensor data from one or more of: an accelerometer; a gyroscope; a
16 magnetometer; a compass (e.g. provided on a or the device comprising the antenna).

17

18 Typically the steerable antenna apparatus comprises one or more sensors configured
19 to measure or calculate the orientation of the antenna (or a or the device comprising
20 the antenna). Typically the steerable antenna apparatus comprises one or more of
21 the following configured to measure the orientation of the antenna: an accelerometer;
22 a gyroscope; a magnetometer; a compass. It may be that the controller is configured
23 to determine an orientation of the antenna from sensor data provided by the said
24 sensors.

25

26 It may be that the method further comprises: determining (or the controller is
27 configured to determine) an orientation of the antenna; and determining (or the
28 controller is configured to determine) the said adjusted principal communication
29 direction of the steerable directional antenna taking into account the determined
30 orientation of the antenna.

31

32 It may be that the selected steering data portion is associated with a particular
33 orientation of the antenna, which may or may not be the same orientation as the
34 determined orientation of the antenna. By taking into account both the selected
35 steering data portion and the orientation of the antenna to determine the adjusted
36 principal communication direction, an adjusted principal communication direction of
37 the antenna can be determined which provides a higher quality wireless link with the

1 electromagnetic signal source (particularly when the orientation with which the
2 selected steering data portion is associated is not the same as the determined
3 orientation of the antenna).

4

5 It may be that the method further comprises selecting (or the controller is configured
6 to select) the said steering data portion from the location specific steering data,
7 and/or determining (or the controller is configured to determine) the said adjusted
8 principal communication direction of the steerable directional antenna, taking into
9 account sensor data from one or more proximity sensors (e.g. one or more proximity
10 sensors of a device comprising the antenna). The sensor data may be indicative of a
11 proximity of an object to the antenna and/or that an object is in close proximity to the
12 antenna. The sensor data may be indicative of a proximity value within a (typically
13 continuous) range of candidate proximity values, or the sensor data may be indicative
14 of a binary decision as to whether there is an object in close proximity of the antenna.

15

16 It may be that the steerable antenna apparatus comprises one or more proximity
17 sensors, typically configured to determine the proximity of one or more (typically
18 external) objects to the antenna (e.g. by detecting the proximity of one or more
19 objects to a or the device comprising the antenna and the proximity sensor(s)), the
20 said object(s) being external to the device) or to determine whether one or more
21 objects are in close proximity to the antenna.

22

23 When an (typically external) object (such as the user of the device comprising the
24 antenna) is in close proximity to the antenna, it is typically preferable to direct the
25 antenna radiation away from the object to improve the quality of communication with
26 the electromagnetic signal source and to avoid directing radiation at the object (which
27 may be a human user). Accordingly by determining the proximity of one or more
28 external objects to the device or by determining whether one or more objects are in
29 close proximity to the antenna, the principal communication direction of the antenna
30 can be adjusted accordingly and a better wireless communications link can be
31 achieved between the antenna and the electromagnetic signal source.

32

33 It may be that the method comprises determining (or the controller is configured to
34 determine) from proximity sensor data the relative direction of one or more (typically
35 external) objects in close proximity to the antenna. For example, it may be that the
36 proximity sensor comprises one or more directional electromagnetic signal sources
37 (e.g. infrared LED) configured to transmit electromagnetic radiation in a given

1 direction, and one or more (typically directional) photodetectors configured to detect
2 reflected radiation from one or more objects in close proximity to the antenna. When
3 an object is detected, it can be deduced that the direction of the said object relative to
4 the antenna corresponds with the transmission direction of the electromagnetic signal
5 source and the principal communication direction of the antenna can be adjusted
6 accordingly.

7

8 It may be that one or more or each of the steering data portions is associated with
9 one or more proximity sensor conditions. It may be that the method comprises
10 determining (or the controller is configured to determine) whether the one or more
11 proximity sensor conditions are met by processing the said proximity sensor data and
12 selecting (or the controller is configured to select) a said steering data portion
13 associated with the proximity sensor conditions responsive to a determination that the
14 said proximity sensor conditions are met. For example, it may be that one or more or
15 each of the said steering data portions is associated with a condition that an object is
16 in close proximity to one of the said proximity sensors and the said steering data
17 portions provide antenna configuration data suitable for directing radiation away from
18 the object while providing a wireless communications link with the electromagnetic
19 signal source.

20

21 Alternatively, it may be that the selected steering data portion is processed together
22 with the proximity sensor data to determine the said adjusted principal
23 communication direction of the steerable directional antenna. For example, it may be
24 that the proximity sensor data is indicative that an object is in close proximity to the
25 antenna (e.g. in a given direction), and the selected steering data portion comprises
26 the location of a terrestrial electromagnetic signal source detectable by the antenna.
27 In this case, the method may comprise determining (or the controller may be
28 configured to determine) the adjusted principal communication direction of the
29 steerable directional antenna taking into account the relative direction from the
30 antenna of the terrestrial electromagnetic signal source and the presence of the
31 object (and optionally, if provided, the direction of the object relative to the antenna).

32

33 It may be that the way in which the user is holding the device (or indeed whether the
34 device is being held at all) can be determined from the sensor data provided by
35 temperature and/or pressure sensors of a or the device comprising the antenna. The
36 way in which the user is holding the device (e.g. positions of the user's fingers on the
37 external surface of the housing of the device) may be indicative of an orientation of

1 the device and/or a proximity of the user to the device, and therefore the preferred
2 principal communication direction of the antenna.

3

4 It may be that the method comprises: selecting (or the controller is configured to
5 select) the said steering data portion from the location specific steering data and/or
6 determining (or the controller is configured to determine) the said adjusted principal
7 communication direction of the steerable directional antenna taking into account
8 sensor data from one or more pressure sensors and/or one or more temperature
9 sensors.

10

11 Typically the said one or more pressure sensors and/or said one or more temperature
12 sensors are pressure/temperature sensors of a or the device comprising the antenna.

13

14 It may be that the temperature and/or pressure sensors are provided on or in
15 communication with an external surface of a housing of the antenna (e.g. an external
16 surface of a housing of a or the device comprising the antenna).

17

18 It may be that the steerable antenna apparatus comprises said one or more pressure
19 sensors and/or said one or more temperature sensors.

20

21 It may be that one or more or each of the steering data portions is associated with
22 one or more temperature sensor conditions and/or pressure sensor conditions. It
23 may be that the method comprises determining (or the controller is configured to
24 determine) whether the one or more temperature sensor conditions and/or the one or
25 more pressure sensor conditions are met by processing the said temperature and/or
26 pressure sensor data and selecting (or the controller is configured to select) the said
27 steering data portion responsive to a determination that the said sensor conditions
28 associated with the said steering data portion are met. For example, it may be that
29 one or more or each of the steering data portions is associated with a condition that
30 one or more (e.g. selected) temperature sensors detect temperatures above a
31 threshold and/or one or more (e.g. selected) pressure sensors detect pressures
32 above a threshold (which indicate a particular orientation of the antenna) and the said
33 steering data portions provide antenna configuration data suitable for directing
34 radiation to (or receiving radiation from) the electromagnetic signal source when the
35 antenna is at that orientation.

36

1 Alternatively, it may be that the controller is configured to process (or the method may
2 comprise processing) the selected steering data portion together with the
3 temperature and/or pressure sensor data to determine the said adjusted principal
4 communication direction of the steerable directional antenna. For example, the
5 temperature and/or pressure sensor data may be indicative that a user is handling
6 the device comprising the antenna, which may be indicative of a (close) proximity of a
7 user to the antenna (which may in turn indicate that the antenna radiation should be
8 directed away from the user); alternatively, the temperature and/or pressure sensor
9 data may be indicative that the device is in a user's pocket, which may be indicative
10 of a (close) proximity of the user to the antenna (which may in turn indicate that the
11 antenna radiation should be directed away from the user).

12

13 A or the device comprising the antenna may comprise one or more (typically two or
14 more) usage modes. A usage mode of the device may be, for example, any of the
15 following: voice call mode, video call mode, browsing internet mode, watching video
16 mode, download mode, upload mode. It may be that the usage mode of the device is
17 indicative of the orientation of the device which, as indicated above, affects the
18 direction of the electromagnetic signal source relative to the antenna. Additionally or
19 alternatively it may be that the usage mode of the device is indicative of a proximity of
20 the user to the device. Accordingly, the usage mode of the device can be used to
21 more accurately determine the adjusted principal communication direction of the
22 antenna.

23

24 It may be that one or more or each of the steering data portions comprises steering
25 data associated with one or more usage modes of the device.

26

27 It may be that the method further comprises: determining (or the controller is
28 configured to determine) a usage mode of a or the device comprising the antenna;
29 and selecting (or the controller is configured to select) the said steering data portion
30 from the location specific steering data taking into account (e.g. associated with) the
31 determined usage mode of the device.

32

33 It may be that the controller is configured to obtain or to receive an indication of the
34 usage mode of the device (e.g. from an operating system of the device).

35

36 Additionally or alternatively, it may be that the method comprises providing (or the
37 memory comprises) usage mode data indicative of one or more parameters specific

1 to (and typically associated with) each of one or more usage modes. The said one or
2 more parameters may comprise any one or more of: an orientation of the device
3 associated with a usage mode; a proximity of a user to a or the device comprising the
4 antenna, said proximity being associated with a usage mode; a location of the user
5 relative to the antenna associated with a usage mode; an antenna steering
6 configuration or direction associated with a usage mode; and a location of the said
7 electromagnetic signal source, the electromagnetic signal source being associated
8 with a usage mode.

9

10 It may be that the said electromagnetic signal source is a base station or access point
11 with which the best quality wireless link can be obtained by the antenna when the
12 device is being used at a particular location. Accordingly, it may be that one or more
13 or each of the said parameters are location specific.

14

15 It may be that the method further comprises: determining (or the controller is
16 configured to determine) a usage mode of a or the device comprising the antenna;
17 and determining (or the controller is configured to determine) the adjusted principal
18 communication direction of the steerable directional antenna taking into account the
19 determined usage mode of the device.

20

21 It may be that the method comprises taking (or the controller is configured to take) the
22 determined usage mode of the device into account by taking into account said one or
23 more parameters associated with the said usage mode (and typically specific to the
24 said user). For example, the method may comprise determining (or the controller is
25 configured to determine) the adjusted principal communication direction of the
26 steerable directional antenna taking into account an orientation of the device and/or a
27 proximity of the user and/or an antenna steering configuration or direction associated
28 with the usage mode.

29

30 Different users may have different ways of holding and/or orienting the device in each
31 usage mode. Accordingly, it may be that the said steering data associated with one
32 or more usage modes of the device is specific to a or the user of the device. For
33 example, it may be that the said steering data portions associated with a usage mode
34 are each derived from usage of the antenna by the user in the said usage mode. By
35 providing steering data associated with one or more usage modes of the device
36 which is specific to the user, the principal communication direction of the antenna can
37 be more accurately adjusted for that user.

1

2 It may be that the said parameters (if provided) are also specific to a or the user of the
3 device. Typically the said usage mode data is provided as part of the said user
4 profile customised for the user of the device.

5

6 It may be that the controller is further configured to determine an activation status
7 (e.g. on or off) of one or more peripheral features of a or the device comprising the
8 antenna and/or whether one or more peripheral devices are coupled to the device
9 (e.g. by way of one or more respective ports of the device) and/or whether one or
10 more peripheral devices coupled to the device (e.g. by way of one or more respective
11 ports of the device) are activated. It may be that the method comprises: selecting (or
12 the controller is configured to select) the said steering data portion from the location
13 specific steering data and/or determining (or the controller is configured to determine)
14 the said adjusted principal communication direction of the steerable directional
15 antenna taking into account an activation status (e.g. on or off) of one or more
16 peripheral features of a or the device comprising the antenna and/or whether one or
17 more peripheral devices are coupled to the device and/or whether one or more
18 peripheral devices coupled to the device are activated. For example, whether a
19 loudspeaker of the device is activated could be indicative of whether a speaker phone
20 mode is activated, which may in turn be indicative of whether a user is in close
21 proximity to the antenna. Similarly, whether headphones are coupled to the device
22 may be indicative of whether a hands free function is being employed, which may in
23 turn be indicative of whether a user is in close proximity to the device. In either case,
24 the preferred adjusted principal communication direction of the antenna would be
25 affected.

26

27 It may be that the method comprises: selecting (or the controller is configured to
28 select) the said steering data portion from the location specific steering data and/or
29 determining (or the controller is configured to determine) the said adjusted principal
30 communication direction of the steerable directional antenna taking into account two
31 or more of: an orientation of the antenna (e.g. pitch and/or yaw and/or roll of the
32 antenna); an orientation of the device comprising the antenna; sensor data from one
33 or more sensors (typically from one or more sensors of a or the device comprising the
34 antenna); sensor data from one or more proximity sensors indicative of whether a
35 user is in close proximity to the antenna; sensor data provided by temperature and/or
36 pressure sensors of a or the device comprising the antenna; a usage mode of the
37 device comprising the antenna; an activation status (e.g. on or off) of one or more

1 peripheral features of a or the device comprising the antenna and/or whether one or
2 more peripheral devices are coupled to the device (e.g. by way of one or more
3 respective ports of the device) and/or whether one or more peripheral devices
4 coupled to the device (e.g. by way of one or more respective ports of the device) are
5 activated.

6

7 It may be that the steerable antenna apparatus comprises a location sensor (e.g. a
8 GPS module or other, e.g. wireless or software based or hybrid location sensor)
9 configured to determine the location of the antenna. For example a or the device
10 comprising the antenna may comprise a location sensor configured to determine the
11 location of the device comprising the antenna. It may be that the method comprises
12 determining (or the controller is configured to determine) the location of the antenna
13 using data (e.g. data identifying local base stations and/or their locations) received
14 from baseband circuitry of a or the device comprising the antenna.

15

16 It may be that the method further comprises: detecting (or the controller is configured
17 to detect) motion of the antenna; and selecting (or the controller is configured to
18 select) a steering data portion from the location specific steering data taking into
19 account the detected motion of the antenna.

20

21 It may be that the said motion comprises a change of orientation of the antenna. It
22 may be that the said motion comprises a change of location of the antenna.

23

24 It may be that motion is detected by comparing successive estimates of the location
25 of the antenna from the location sensor. Additionally or alternatively it may be that
26 the steerable antenna apparatus comprises a movement sensor (e.g. accelerometer)
27 configured to detect motion of the antenna.

28

29 It may be that the method comprises: predicting (or the controller is configured to
30 predict) a future location of the antenna (e.g. from the said detected motion of the
31 antenna); and selecting (or the controller is configured to select) a steering data
32 portion specific to that future location.

33

34 It may be that the method further comprises determining (or the controller is
35 configured to determine or receive) the direction of motion of the antenna (e.g. by
36 comparing subsequent or successive estimates of the location of the device by the
37 location sensor). It may be that the steerable antenna apparatus comprises a

1 direction sensor (e.g. compass) configured to determine a direction of movement of
2 the device.

3

4 It may be that the method further comprises: determining (or the controller is
5 configured to determine) the orientation of the antenna; and taking (or the controller is
6 configured to take) the orientation of the antenna into account to determine the
7 direction of motion of the antenna (e.g. it may be that directional information output by
8 a compass assumes a particular orientation of the device, and the orientation
9 information allows more accurate directional information to be deduced).

10

11 The method typically comprises predicting (or the controller is configured to predict)
12 the said future location of the device taking into account the said direction of
13 movement of the device.

14

15 It may be that the method further comprises determining (or the controller is
16 configured to determine) a speed (or velocity) of movement of the antenna from the
17 said detected motion of the antenna. Typically the method comprises predicting (or
18 the controller is configured to predict) the said future location of the antenna taking
19 into account the said speed (or velocity) of movement of the antenna.

20

21 It may be that the method comprises adjusting (or the controller is configured to
22 adjust) the principal communication direction of the antenna, e.g. periodically or
23 responsive to detected motion of the antenna. It may be that the method comprises
24 adjusting (or the controller is configured to adjust) the principal communication
25 direction of the antenna more often responsive to a determined increase in speed of
26 movement of the antenna.

27

28 It may be that the method further comprises: detecting (or the controller is configured
29 to detect) motion of the antenna; and determining (or the controller is configured to
30 determine) the adjusted principal communication direction of the steerable directional
31 antenna taking into account the detected motion of the antenna.

32

33 It may be that the method comprises: predicting (or the controller is configured to
34 predict) a future location of the antenna taking into account the said detected motion
35 of the antenna; and determining (or the controller is configured to determine) the
36 adjusted principal communication direction of the steerable directional antenna
37 suitable for the said future location.

1

2 It may be that the principal communication direction of the steerable directional
3 antenna is adjusted in accordance with the said adjusted principal communication
4 direction (e.g. by the controller) responsive to a determination that the antenna has
5 reached the predicted future location. Alternatively the step of adjusting the principal
6 communication direction of the steerable directional antenna in accordance with the
7 said adjusted principal communication direction is performed (e.g. by the controller)
8 before (e.g. shortly before) the antenna has reached the predicted future location.

9

10 It may be that the method comprises: providing (or the memory comprises)
11 movement pattern data indicative of one or more predetermined patterns of
12 movement of the user (e.g. by providing movement pattern data indicative of one or
13 more predetermined patterns of movement of the antenna); determining (or the
14 controller is configured to determine) from the determined location of the antenna that
15 the antenna is following a said predetermined pattern of movement; and predicting
16 (or the controller is configured to predict) a future location of the antenna from the
17 said pattern of movement, wherein the said selected steering data portion is specific
18 to the said future location.

19

20 The patterns of movement of the antenna may comprise one or more routes which
21 have been previously followed by a user of the antenna (e.g. by the antenna itself, or
22 by a or the device comprising the antenna). It may be that the method comprises
23 determining (or the controller is configured to determine) from the determined location
24 of the antenna that the antenna is following a said pattern of movement on the basis
25 that the determined location is (or two or more successive locations are) on a route
26 previously followed by the antenna.

27

28 Typically by adjusting the principal communication direction of the antenna in
29 accordance with the determined adjusted principal communication direction of the
30 antenna, the antenna is brought into (typically radio frequency) wireless
31 communication with the terrestrial electromagnetic signal source, or a wireless
32 (typically radio frequency) communications link between the antenna and the
33 terrestrial electromagnetic signal source is improved.

34

35 The antenna typically comprises two or more (e.g. an array of) antenna elements
36 (such as the antenna described in WO2008/152428 which is incorporated in full
37 herein by reference) which can be configured to directionally transmit and/or receive

1 (typically radio frequency) electromagnetic communication signals by electronic beam
2 forming. It may be that the antenna elements have positions and/or orientations
3 which are fixed relative to each other. It may be that the antenna elements have
4 positions and/or orientations which are fixed relative to a housing of a or the device
5 comprising the antenna. The antenna elements of the antenna may comprise one or
6 more transmitter antenna elements (e.g. operable to transmit radio communications
7 signals such as 2G, 2.5G, 3G, 4G, 5G mobile telecommunications signals, Bluetooth
8 signals, Wi-Fi signals or Wi-Max signals) and/or one or more receiver antenna
9 elements (e.g. operable to receive radio communications signals such as 2G, 2.5G,
10 3G, 4G, 5G mobile telecommunications signals, Bluetooth signals, Wi-Fi signals or
11 Wi-Max signals) and/or one or more transceiver antenna elements (e.g. operable to
12 transmit and receive radio communications signals such as 2G, 2.5G, 3G, 4G, 5G
13 mobile telecommunications signals, Bluetooth signals, Wi-Fi signals or Wi-Max
14 signals). It may be that the antenna elements are implemented in semiconductor. It
15 may be that the method comprises steering the antenna elements using one or more
16 MEMS devices (or the antenna apparatus comprises one or more MEMS devices
17 configured to steer the antenna elements). It may be that the principal
18 communication direction of the antenna is selected electronically (e.g. by combining
19 signals transmitted or detected by the antenna elements in particular ways). It may
20 be that the step of adjusting the principal communication direction comprises steering
21 the principal communication direction of the antenna electronically (e.g. by adjusting
22 a principal beamforming direction of the antenna).

23

24 The antenna may comprise a sector antenna comprising two or more sectors which
25 can be selectively activated and deactivated to transmit and/or receive (typically radio
26 frequency) electromagnetic communication signals to or from selected
27 communication directions, the antenna being steerable by activating and deactivating
28 selected sectors of the antenna. It may be that the step of adjusting the principal
29 communication direction is performed by activating and deactivating one or more
30 respective sectors of the antenna.

31

32 The antenna may be mechanically rotatable so as to transmit and/or receive typically
33 radio frequency) electromagnetic communication signals to or from selected
34 communication directions, the antenna being steerable by mechanically rotating it
35 from one configuration to another. It may be that the step of adjusting the principal
36 communication direction comprises mechanically rotating the antenna.

37

1 It may be that the method comprises measuring (or the controller is configured to
2 measure) a signal strength of one or more electromagnetic signals received by the
3 antenna from the said electromagnetic signal source. It may be that the method
4 comprises measuring (or the controller is configured to measure) a quality of the
5 wireless link between the antenna and the electromagnetic signal source.

6

7 It may be that the steps of: selecting a steering data portion from the location specific
8 steering data taking into account the determined location of the antenna (e.g. a
9 steering data portion associated with the determined location); determining an
10 adjusted principal communication direction of the steerable directional antenna taking
11 into account the said selected steering data portion; and adjusting the principal
12 communication direction of the steerable directional antenna in accordance with the
13 said adjusted principal communication direction are performed periodically or
14 responsive to a determination that a measured signal strength of one or more
15 electromagnetic signals received by the antenna from the said electromagnetic signal
16 source does not meet one or more signal strength criteria or responsive to a
17 determination that a quality of the wireless link between the antenna and the
18 electromagnetic signal source does not meet one or more link quality criteria.

19

20 It may be that the steps of determining an adjusted principal communication direction
21 of the steerable directional antenna taking into account the said selected steering
22 data portion; and adjusting the principal communication direction of the steerable
23 directional antenna in accordance with the said adjusted principal communication
24 direction are performed periodically or responsive to a determination that a measured
25 signal strength of one or more electromagnetic signals received by the antenna from
26 the said electromagnetic signal source does not meet one or more signal strength
27 criteria or responsive to a determination that a quality of the wireless link between the
28 antenna and the electromagnetic signal source does not meet one or more link
29 quality criteria.

30

31 It may be that the principal communication direction of the antenna is adjusted
32 iteratively taking into account a quality of a (typically radio frequency) wireless
33 communications link between the antenna and the terrestrial electromagnetic signal
34 source. For example, it may be that the method comprises: determining (or the
35 controller is configured to determine) the (first) adjusted principal communication
36 direction taking into account the selected steering data portion; adjusting (or the
37 controller is configured to adjust) the principal communication direction in accordance

1 with the adjusted principal communication direction; measuring (or the controller is
2 configured to measure) a quality of a wireless communications link between the
3 antenna and the terrestrial electromagnetic signal source (e.g. strength of signals
4 received by the antenna from the electromagnetic signal source); determining (or the
5 controller is configured to measure) a second adjusted principal communication
6 direction taking into account the measured quality of the wireless communications
7 link (e.g. responsive to the measured quality of the wireless communications link not
8 meeting one or more link quality criteria at the (first) principal communication
9 direction); and adjusting (or the controller is configured to adjust) the principal
10 communication direction in accordance with the second adjusted principal
11 communication direction to thereby improve the wireless communications link
12 between the antenna and the electromagnetic signal source.

13

14 It may be that the method comprises providing (or the memory comprises) a target
15 wireless communications link quality. It may be that the method comprises adjusting
16 (or the controller is configured to adjust) the principal communication direction of the
17 antenna iteratively until the said target wireless communications link quality is met. It
18 may be that the method comprises adjusting (or the controller is configured to adjust)
19 the principal communication direction of the antenna iteratively within a first
20 adjustment range responsive to a determination that the measured wireless
21 communications link quality is within a first target range of the target wireless
22 communications link quality. It may be that the method comprises adjusting (or the
23 controller is configured to adjust) the principal communication direction of the
24 antenna iteratively within a second adjustment range greater than the first adjustment
25 range responsive to a determination that the measured wireless communications link
26 quality is within a second target range of the target wireless communications link
27 quality greater than the first target range (and typically outside the first target range).

28

29 It may be that the method comprises determining (or the controller may be configured
30 to determine) a frequency channel on which the antenna is communicating (or is
31 trying to communicate) with the electromagnetic signal source. It may be that the
32 method further comprises selecting (or the controller is configured to select) a said
33 steering data portion from the location specific steering data and/or determining (or
34 the controller is configured to determine) the said adjusted principal communication
35 direction of the steerable directional antenna taking into account (or responsive to)
36 the said frequency channel (e.g. to reduce or avoid interference or to increase the
37 security of the link).

1

2 It may be that the controller is configured to obtain (or the method may comprise
3 obtaining) assistance data from a general database comprising locations of one or
4 more electromagnetic signal sources (e.g. base station locations and/or WiFi access
5 point locations and/or WiFi network locations). It may be that the method comprises
6 obtaining (or the controller is configured to obtain) the location of a second
7 electromagnetic signal source from the general database; determining (or the
8 controller is configured to determine) a second adjusted principal communication
9 direction taking into account the location of the second electromagnetic signal source;
10 and adjusting (or the controller is configured to adjust) the principal communication
11 direction of the steerable directional antenna in accordance with the said second
12 adjusted principal communication direction. It may be that these steps are performed
13 for example when the said antenna changes location (e.g. to a location not previously
14 occupied by the antenna) such that the said electromagnetic signal source is out of
15 range of the antenna, and the antenna is required to communicate with a different
16 (i.e. the second) electromagnetic signal source.

17

18 It may be that the method further comprises: providing (or the memory comprising)
19 location specific power level data comprising one or more power level data portions,
20 each of the power level data portions being specific to each of one or more locations
21 (e.g. the said one or more locations with which the steering data portions are
22 associated), the said power level data portions being indicative of respective power
23 level configurations of one or more antenna amplifiers configured to adjust a power
24 level of (e.g. amplify) signals to be transmitted and/or received by the antenna (e.g.
25 which enable the antenna to communicate with the terrestrial electromagnetic signal
26 source from the said locations); selecting (or the controller being configured to select)
27 a power level data portion from the said power level data taking into account the
28 determined location of the device; determining (or the controller being configured to
29 determine) a power level configuration of the antenna amplifier(s) taking into account
30 the selected power level data portion; and configuring (or the controller being
31 configured to configure) the antenna amplifier(s) in accordance with the said
32 determined power level configuration.

33

34 It may be that the said one or more antenna amplifiers comprises one or more power
35 amplifiers configured to amplify signals to be transmitted by the antenna. It may be
36 that the said one or more antenna amplifiers comprise one or more low noise
37 amplifiers configured to amplify signals received by the antenna.

1

2 It may be that the steerable antenna apparatus comprises one or more antenna
3 amplifiers configured to adjust a power level of (e.g. amplify) signals to be transmitted
4 and/or received by the antenna and that the controller is configured to set a gain of
5 (e.g. each of) the antenna amplifier(s) in accordance with the said determined power
6 level configuration.

7

8 It may be that the antenna amplifiers have respective gains which are greater than
9 unity, less than unity or unity (e.g. in the said determined power level configuration).
10 Accordingly, it may be that the one or more antenna amplifiers comprise one or more
11 signal boosters and/or one or more signal attenuators (e.g. in the said determined
12 power level configuration). It may be that the one or more antenna amplifiers
13 comprise a plurality of antenna amplifiers. It may be that amplifiers of the said
14 plurality of antenna amplifiers have respective gains which are different from each
15 other (e.g. in the determined power level configuration). It may be that one or more
16 (or each) of the antenna amplifiers comprises amplifier circuitry, and that the amplifier
17 gain is set by setting the gain of the amplifier circuitry. It may be that the amplifier
18 circuitry of said one or more (or each) of the antenna amplifiers comprises signal
19 boosting circuitry and/or signal attenuating circuitry. It may be that one or more of the
20 antenna amplifier(s) comprises one or more (typically two or more, typically
21 individually selectable) beamforming weightings applied to respective phase shifted
22 signals combined in a beamforming algorithm. In this case, it may be that the
23 controller is configured to set the antenna gain by adjusting the said beamforming
24 weightings.

25

26 It will be understood that the steps of selecting the power level data portion and/or
27 determining the power level configuration of the antenna amplifier(s) may also
28 comprise taking into account sensor data received from one or more sensors. For
29 example, sensor data from a proximity sensor may indicate the proximity of a user to
30 the antenna. As a result, it may be that the determined adjusted principal
31 communication direction does not point directly at the terrestrial electromagnetic
32 signal source. Accordingly, it may be necessary to increase the power level to
33 compensate. The power level may then be iteratively adjusted to meet a or the target
34 quality of wireless communications link between the antenna and the said terrestrial
35 electromagnetic signal source.

36

1 It may be that the said power level data is derived from usage of the antenna by a or
2 the user of the antenna. Typically the said power level data is provided as part of the
3 said user profile customised for the user of the antenna.

4

5 It may be that the method comprises configuring (or the controller may be configured
6 to configure) the antenna amplifier(s) in accordance with the said determined power
7 level configuration by adjusting an amplification provided by an amplifier to signals
8 which are passed to the antenna for transmission. For example, the method may
9 comprise adjusting the amplification provided by a power amplifier to signals which
10 are to be transmitted by the antenna.

11

12 It may be that the method comprises configuring (or the controller may be configured
13 to configure) the antenna amplifier(s) in accordance with the said determined power
14 level configuration by adjusting an amplification provided by an amplifier to signals
15 which are received by the antenna. For example, the method may comprise adjusting
16 the amplification provided by a low noise amplifier to signals which are received by
17 the antenna.

18

19 It will be understood that the steps of selecting the power level data portion and/or
20 determining the power level configuration of the antenna may also comprise taking
21 into account a usage mode of a or the device comprising the antenna. For example,
22 a usage mode may involve having to communicate with the said electromagnetic
23 signal source over a greater range than in other usage modes or a usage mode may
24 require a higher quality link to provide a higher bit-rate (e.g. if large portions of data
25 are to be downloaded). In such cases it may be that the step of selecting the power
26 level data portion and/or determining the power level configuration of the antenna
27 amplifier(s) comprises increasing the gain of the antenna amplifier in order to provide
28 the higher quality bit-rate or the greater range.

29

30 It may be that the method further comprises: selecting (or the controller being
31 configured to select) the said steering data portion taking into account a type of
32 (typically wireless, typically radio frequency) communication performed by the
33 antenna and/or by the terrestrial electromagnetic signal source.

34

35 It may be that selecting the said steering data portions take into account a
36 communications protocol the antenna and/or the terrestrial electromagnetic signal
37 source are configured to employ. For example, it may be that different steering data

1 portions are provided for different communications protocols (e.g. Bluetooth, Wifi, 2G,
2 GPRS, 3G, 4G, 5G) which can be performed by a or the device comprising the
3 antenna (and optionally one or more other antenna), and the method comprises
4 selecting (or the controller is configured to select) the said steering data portion
5 taking into account the type of communications (e.g. the communications protocol)
6 employed by the antenna and/or by the terrestrial electromagnetic signal source.

7

8 Typically, the antenna is provided on a (typically electronic) wireless communications
9 device, such as a handheld or wearable wireless communications device (e.g. smart
10 watch), wearable sensor, mobile wireless communications device, portable wireless
11 communications device, mobile phone, mobile smartphone, phablet, tablet, laptop or
12 netbook computer. The wireless communications device may alternatively comprise a
13 picocell, femtocell, base station, signal node, beacon, router or repeater.

14

15 Typically the antenna is an antenna of an RF front end of a mobile wireless
16 communications device.

17

18 It may be that the method further comprises communicating (or the controller is
19 configured to bring the antenna into communication) with the terrestrial
20 electromagnetic signal source in the said adjusted principal communication direction.

21

22 It may be that the method is performed on a or the device comprising the antenna. It
23 may be that the method is performed partly on the device comprising the antenna and
24 partly on one or more server computers with which the device comprising the antenna
25 can communicate.

26

27 It may be that the memory is provided on the device comprising the antenna. It may
28 be that the memory is provided on one or more server computers with which the
29 device can communicate. It may be that the memory is distributed across the device
30 and one or more server computers with which the device can communicate.

31

32 It may be that the controller is provided on the device comprising the antenna. It may
33 be that the controller is provided on one or more server computers with which the
34 device can communicate. It may be that the controller is distributed across the device
35 and one or more server computers with which the device can communicate.

36

1 It may be that the method comprises determining (or the controller may be configured
2 to determine) a frequency channel on which the antenna is communicating (or is
3 trying to communicate) with the electromagnetic signal source. It may be that the
4 method comprises adjusting (or the controller may be configured to adjust) a
5 frequency response of one or more antenna amplifiers configured to adjust a power
6 level of (e.g. amplify) signals to be transmitted and/or received by the antenna taking
7 into account (or responsive to) the said frequency channel, typically to improve the
8 performance of the amplifier(s) at one or more frequencies of the said frequency
9 channel. This step is particularly important when the frequency channel is at the
10 periphery of a frequency range comprising all available frequency channels for a
11 particular wireless communications type, typically because it may be that by default
12 the frequency response of the amplifier is tuned for peak performance at the centre of
13 the said frequency range. Accordingly, by adjusting the frequency response of the
14 amplifier(s) taking into account the said frequency channel, the quality of the
15 communications link between the antenna and the electromagnetic signal source is
16 improved.

17

18 It may be that the method comprises adjusting (or the controller may be configured to
19 adjusting) the frequency response of one or more antenna amplifiers configured to
20 adjust a power level of (e.g. amplify) signals which are to be transmitted by the
21 antenna taking into account (or responsive to) the said frequency channel, typically to
22 improve the performance of the amplifier(s) at one or more frequencies of the said
23 frequency channel. For example, the method may comprise adjusting the frequency
24 response of a power amplifier from which signals are passed to the antenna for
25 transmission taking into account (or responsive to) the said frequency channel,
26 typically to improve the performance of the amplifier at one or more frequencies of the
27 said frequency channel.

28

29 It may be that the method comprises adjusting (or the controller may be configured to
30 adjusting) the frequency response of one or more antenna amplifiers configured to
31 adjust a power level of (e.g. amplify) signals received by the antenna taking into
32 account (or responsive to) the said frequency channel, typically to improve the
33 performance of the amplifier at one or more frequencies of the said frequency
34 channel. For example, the method may comprise adjusting the frequency response of
35 a low noise amplifier configured to amplify signals received by the antenna taking into
36 account (or responsive to) the said frequency channel, typically to improve the

1 performance of the amplifier at one or more frequencies of the said frequency
2 channel.

3

4 It may be that the method comprises adjusting (or the controller may be configured to
5 adjusting) the frequency response of a tunable filter configured to band pass filter
6 signals which are to be transmitted by the antenna or signals which are received by
7 the said antenna, taking into account the said frequency channel.

8

9 It may be that one or more or each said steering data portion is associated with an
10 expected link quality of a wireless communications link between the antenna and the
11 electromagnetic signal source. It may be that the method comprises comparing (or
12 the controller is configured to compare) a current link quality of a wireless link
13 between the said antenna and the electromagnetic signal source with the said
14 expected link quality and selecting the said steering data portion responsive to a
15 determination that the expected link quality is greater than the said current link
16 quality.

17

18 Typically, when the antenna is a transmitter antenna or a transceiver antenna in
19 transmitter mode, the principal communication direction is the centre of the radiation
20 pattern/beam emitted by the antenna.

21

22 Typically, when the antenna is a receiver antenna or a transceiver antenna in
23 receiver mode, the principal communication direction is the centre of the field of view
24 of the antenna.

25

26 A third aspect of the invention provides a method of generating location specific
27 steering data for a steerable directional antenna, the location specific steering data
28 comprising one or more (typically two or more) steering data portions, each of the
29 steering data portions being specific to a respective (typically absolute) location, the
30 method comprising: providing the said steerable directional antenna at a location;
31 adjusting a principal communication direction of the antenna to thereby provide a
32 (typically radio frequency) wireless communications link between the antenna and a
33 terrestrial electromagnetic signal source meeting one or more link criteria; and storing
34 the said location together with a steering data portion related to, or derived from, the
35 said adjusted principal communication direction.

36

1 A fourth aspect of the invention provides steerable directional antenna apparatus
2 comprising: a steerable directional antenna; a memory; and a controller comprising
3 one or more computer processors, the controller being configured to: determine a
4 (typically absolute) location of the antenna; adjust a principal communication direction
5 of the antenna to thereby provide a (typically radio frequency) wireless
6 communications link between the antenna and a terrestrial electromagnetic signal
7 source meeting one or more link criteria; and store in the memory the said location
8 together with a steering data portion related to, or derived from, the said adjusted
9 principal communication direction.

10

11 It will be understood that the controller of the fourth aspect of the invention may be
12 configured to perform any of the steps of the method according to the third aspect of
13 the invention.

14

15 It may be that the step of adjusting (or the controller may be configured to adjust) the
16 principal communication direction of the antenna to thereby provide a wireless
17 communications link between the antenna and a terrestrial electromagnetic signal
18 source meeting one or more link criteria takes into account a location of the terrestrial
19 electromagnetic signal source obtained from a general database (which is typically in
20 communication with the controller).

21

22 It may be that the method comprises determining (or the controller is configured to
23 determine, e.g. receive) the said location of the steerable directional antenna. It may
24 be that the method comprises receiving (or the controller is configured to receive) the
25 said location of the antenna, for example from a location sensor (e.g. of a device
26 comprising the antenna) configured to determine the location of the antenna (e.g. by
27 determining the location of a device comprising the antenna).

28

29 The method may further comprise storing (or the controller may be configured to
30 store) an identifier of the electromagnetic signal source together with the said location
31 and steering data.

32

33 It may be that the said steering data portion comprises any one or more of: an
34 estimated location of the said terrestrial electromagnetic signal source (which may be
35 specified in signals transmitted by the terrestrial electromagnetic signal source or
36 deduced by triangulation, for example); antenna configuration data representing the
37 said adjusted principal communication direction of the antenna; and data

1 representing the adjusted principal communication direction (e.g. from which said
2 configuration data can be derived).

3

4 It may be that the method comprises generating movement pattern data indicative of
5 one or more patterns of movement of the user, for example by: determining a plurality
6 of locations of the user (e.g. by determining a plurality of locations of the antenna or
7 of the device); identifying one or more patterns of movement of the antenna from the
8 said plurality of locations (e.g. one or more paths or routes followed once, or more
9 than once by the user carrying the antenna); and generating movement pattern data
10 indicative of the said identified patterns of movement.

11

12 The patterns of movement of the user may comprise one or more routes followed by
13 the user (e.g. when carrying the antenna).

14

15 It may be that the method further comprises: determining (or the controller is
16 configured to determine) an orientation of the antenna (e.g. by determining
17 orientation of a device comprising antenna), typically when the wireless
18 communications link meets the said link criteria; and storing (or the controller is
19 configured to store in the memory) data representing the said orientation of the
20 antenna together with said steering data portion and location.

21

22 The steerable antenna apparatus may comprise one or more orientation sensors
23 configured to measure (or the method may comprise measuring) the orientation of
24 the antenna. For example, the steerable antenna apparatus may comprise any one
25 or more of the following configured to measure the orientation of the antenna: an
26 accelerometer; a gyroscope; a magnetometer; a compass. Alternatively, the antenna
27 apparatus may be configured to measure (or the method may comprise measuring)
28 the orientation of the antenna by adjusting the principal communication direction of
29 the antenna. For example, if the location of the electromagnetic signal source is
30 known, the method may comprise (e.g. iteratively) adjusting (or the controller may be
31 configured to (e.g. iteratively) adjust) the principal communication direction of the
32 antenna a plurality of times; measuring signal strengths of one or more
33 electromagnetic signals received from the electromagnetic signal source or
34 measuring link qualities of the wireless link between the antenna and the
35 electromagnetic signal source at each of the principal communication directions; and
36 determining the orientation of the antenna taking into account the known location of

1 the electromagnetic signal source and the measured received signal strengths or link
2 qualities.

3

4 It may be that the method further comprises: determining (or the controller is
5 configured to determine) sensor data from one or more sensors, typically when the
6 wireless communications link meets the said link criteria; and storing the said sensor
7 data together with said steering data portion and location.

8

9 The sensors may comprise any one or more of the following: orientation sensor
10 configured to determine the orientation of the antenna; proximity sensor configured to
11 determine proximity of one or more external objects to the antenna; temperature
12 sensor configured to determine a temperature of an external surface of a housing of a
13 device comprising the antenna; a pressure sensor configured to determine a physical
14 pressure exerted on an external surface of a housing of a device comprising the
15 antenna; and a usage mode sensor configured to determine a usage mode of the
16 device comprising the antenna.

17

18 It may be that the method further comprises: determining an activation status (e.g. on
19 or off) of one or more peripheral features of a or the device comprising the antenna
20 and/or whether one or more peripheral devices are coupled to the device and/or
21 whether one or more peripheral devices coupled to the device are activated, typically
22 when the wireless communications link meets the said link criteria; and storing (or the
23 controller is configured to store) data representing the said activation status (e.g. on
24 or off) of one or more peripheral features of a or the device comprising the antenna
25 and/or whether one or more peripheral devices are coupled to the device and/or
26 whether one or more peripheral devices coupled to the device are activated together
27 with the steering data and location.

28

29 It may be that the method further comprises: determining (or the controller is
30 configured to determine) a usage mode of a device comprising the antenna, typically
31 when the wireless communications link meets the said link criteria; and storing (or the
32 controller is configured to store in the memory) usage mode data representing the
33 said usage mode together with said steering data portion and location.

34

35 It may be that the method further comprises: determining (or the controller is
36 configured to determine) a frequency channel of the wireless communications link,
37 typically when the wireless communications link meets the said link criteria; and

1 storing (or the controller is configured to store in the memory) frequency channel data
2 together with said steering data portion and location.

3

4 It may be that the method further comprises: determining (or the controller is
5 configured to determine) a communications type of the wireless communications link,
6 typically when the wireless communications link meets the said link criteria; and
7 storing (or the controller is configured to store in the memory) communications type
8 data representing the said communications type of the wireless communications link
9 together with said steering data portion and location.

10

11 It may be that the method further comprises: determining (or the controller is
12 configured to determine) a quality of the said wireless communications link, typically
13 when the wireless communications link meets the said link criteria; and storing (or the
14 controller is configured to store in the memory) link quality data indicative of the
15 quality of the said wireless communications link together with said steering data
16 portion and location.

17

18 It may be that the method further comprises: determining (or the controller is
19 configured to determine) power level data indicative of respective power level
20 configurations of one or more antenna amplifiers configured to adjust a power level of
21 (e.g. amplify) signals to be transmitted and/or received by the antenna when the
22 wireless communications link meets the said link criteria; and storing (or the controller
23 is configured to store in the memory) data representing the said power level data
24 together with said steering data portion and location.

25

26 It may be that the said link criteria comprise a determination that a wireless
27 communications link has been established between the antenna and the terrestrial
28 electromagnetic signal source (e.g. when previously there was no such link).

29

30 It may be that the said link criteria comprise a determination that a wireless
31 communications link has been established between the antenna and the terrestrial
32 electromagnetic signal source having a bit rate exceeding a predetermined threshold.

33

34 It may be that the said link criteria comprise a determination that a wireless
35 communications link has been established between the antenna and the terrestrial
36 electromagnetic signal source having a bit error rate below a predetermined
37 threshold.

1

2 It may be that the said link criteria comprise a determination that a wireless
3 communications link has been established between the antenna and the terrestrial
4 electromagnetic signal source having a signal to noise ratio above a predetermined
5 threshold.

6

7 It may be that the said link criteria comprise a determination that a wireless
8 communications link has been established between the antenna and the terrestrial
9 electromagnetic signal source having a received signal strength greater than a
10 predetermined threshold.

11

12 It may be that the step of adjusting the principal communication direction of the
13 antenna comprises adjusting (or the controller is configured to adjust) the principal
14 communication direction of the antenna a plurality of times to provide a plurality of
15 adjusted principal communication directions and selecting (or the controller is
16 configured to select) the principal communications direction of the said plurality of
17 principal communication directions which provides the highest quality wireless
18 communications link between the antenna and the terrestrial electromagnetic signal
19 source. It may be that the said plurality of adjusted principal communication
20 directions comprises each possible principal communication direction of the antenna.

21

22 It may be that the principal communication direction of the antenna is adjustable
23 across a first range. It may be that the step of adjusting the principal communication
24 direction of the antenna comprises adjusting (or the controller is configured to adjust)
25 the principal communication direction of the antenna across a second range, the
26 second range being a subset of the first range, responsive to a determination that a
27 battery level (i.e. the electrical power available from a battery) of a or the device
28 comprising the antenna is below a predetermined threshold.

29

30 It may be that the controller is a controller of a or the device comprising the antenna,
31 or it may be that the controller is a controller of one or more server computers in
32 communication with a or the device comprising the antenna, but more typically the
33 controller is distributed across a or the device comprising the antenna and one or
34 more server computers. It may be that the controller is implemented in hardware or in
35 computer software, but more typically the controller is implemented in a combination
36 of hardware and software.

37

1 It may be that the said memory is a memory of a or the device comprising the
2 antenna, but more typically the said memory is a memory of one or more server
3 computers. Alternatively, the memory is distributed across a or the device comprising
4 the antenna and one or more server computers.

5

6 It may be that the method comprises storing (or the controller is configured to store)
7 the said steering data portion and the said location on a memory of one or more
8 server computers (or the said memory is a memory of one or more server
9 computers). It may be that the step of storing the said steering data portion and the
10 said location is performed (or the controller is configured to store the said steering
11 data portion in the memory) as part of a batch update comprising storing a plurality of
12 steering data portions together with a respective plurality of locations. It may be that
13 the step of storing the said steering data portion and the said location comprises:
14 determining (or the controller is configured to determine) a battery level of a or the
15 device comprising the antenna; and uploading (or the controller is configured to
16 upload) the said steering data portion and data representing the said location to the
17 said memory of the server computer(s) responsive to a determination that the battery
18 level is greater than a predetermined threshold. It may be that the method comprises
19 determining (or the controller is configured to determine) a battery level of a or the
20 device comprising the antenna; and not uploading (or the controller is configured to
21 not upload) the said steering data portion and data representing the said location to
22 the said memory of the server computer(s) responsive to a determination that the
23 battery level is less than a predetermined threshold.

24

25 It may be that the step of adjusting the principal communication direction of the
26 antenna comprises (or the controller is configured to adjust the principal
27 communication direction of the antenna by) mechanically rotating a rotatable antenna
28 (typically at the said location).

29

30 It may be that the step of adjusting the principal communication direction of the
31 antenna comprises (or the controller is configured to adjust the principal
32 communication direction of the antenna by) activating and/or deactivating one or
33 more sectors of a sector antenna (typically at the said location).

34

35 It may be that the antenna comprises a plurality of antenna elements (such as the
36 antenna described in WO2008/152428 which is incorporated in full herein by
37 reference). It may be that detected signals from each of the antenna elements are

1 passed through respective phase shifters to provide a respective plurality of phase
2 shifted signals. It may be that the phase shifted signals are then combined to form
3 the directional signal transmitted or received by the antenna.

4

5 It may be that the step of adjusting the principal communication direction of the
6 antenna comprises (or the controller is configured to adjust the principal
7 communication direction of the antenna by) steering the principal communication
8 direction of the antenna electronically (e.g. by adjusting a principal beamforming
9 direction of the antenna). For example, it may be that the step of adjusting the
10 principal communication direction of the antenna comprises (or the controller is
11 configured to adjust the principal communication direction of the antenna by)
12 adjusting beamforming parameters (e.g. coefficients, weightings, phase shifts)
13 associated with antenna elements of the antenna array.

14

15 It may be that the locations to which the respective steering data portions are specific
16 are points or loci of points in space. The said points or loci may be represented, for
17 example, by (two-dimensional or three-dimensional) location co-ordinates (e.g.
18 longitude, latitude and, for three dimensional co-ordinates, altitude) or one or more
19 ranges of (two-dimensional or three-dimensional) location co-ordinates.

20

21 Typically the method comprises storing (or the controller is configured to store) the
22 said location together with steering data related to, or derived from, the said adjusted
23 principal communication direction (optionally together with any of the other data
24 storage discussed above) to thereby generate location specific steering data for a
25 steerable directional antenna which is specific to a user (e.g. a user of a or the device
26 comprising the antenna).

27

28 It may be that the method comprises storing (or the controller is configured to store)
29 the said location together with a steering data portion related to, or derived from, the
30 said adjusted principal communication direction (optionally together with any of the
31 other data storage discussed above) to thereby generate location specific steering
32 data for a steerable directional antenna which is customised for a user (e.g. a user of
33 a or the device comprising the antenna).

34

35 It may be that the method comprises storing (or the controller is configured to store)
36 the said location together with a steering data portion related to, or derived from, the
37 said adjusted principal communication direction (optionally together with any of the

1 other data storage discussed above) to thereby customise a user profile associated
2 with a user (e.g. of a or the device comprising the antenna).

3

4 A fifth aspect of the invention provides a non-transitory computer readable medium
5 tangibly embodying computer program code for causing a computer to adjust a
6 principal communication direction of a steerable directional antenna for
7 communicating with a terrestrial electromagnetic signal source by: receiving location
8 specific steering data comprising one or more steering data portions, each of the
9 steering data portions being specific to a respective location; receiving a location of
10 the steerable directional antenna; selecting a steering data portion from the location
11 specific steering data taking into account the received location of the antenna;
12 determining an adjusted principal communication direction of the steerable directional
13 antenna taking into account the said selected steering data portion; and adjusting the
14 principal communication direction of the steerable directional antenna in accordance
15 with the said adjusted principal communication direction.

16

17 A sixth aspect of the invention provides a non-transitory computer readable medium
18 tangibly embodying computer program code for causing a computer to generate
19 location specific steering data for a steerable directional antenna, the location specific
20 steering data comprising one or more (typically two or more) steering data portions,
21 each of the steering data portions being specific to a respective (typically absolute)
22 location, by: receiving a location of the antenna; adjusting a principal communication
23 direction of the antenna to thereby provide a (typically radio frequency) wireless
24 communications link between the antenna and a terrestrial electromagnetic signal
25 source meeting one or more link criteria; and storing the said location together with a
26 steering data portion related to, or derived from, the said adjusted principal
27 communication direction.

28

29 A seventh aspect of the invention provides a method of controlling the power level of
30 signals to be transmitted and/or received by an antenna (typically a steerable
31 directional antenna), the method comprising: providing location specific power level
32 data comprising one or more power level data portions, each of the power level data
33 portions being specific to each of one or more locations, the said power level data
34 portions being indicative of respective power level configurations of one or more
35 antenna amplifiers configured to adjust a power level of (e.g. amplify) signals to be
36 transmitted and/or received by the antenna; determining a location of the antenna;
37 selecting a power level data portion from the said power level data taking into

1 account the determined location of the antenna; determining a power level
2 configuration of the antenna amplifier(s) taking into account the selected power level
3 data portion; and configuring the antenna amplifier(s) in accordance with the said
4 determined power level configuration.

5

6 An eighth aspect of the invention provides antenna apparatus comprising: an antenna
7 (typically a steerable directional antenna) for communicating with a terrestrial
8 electromagnetic signal source; a memory comprising location specific power level
9 data comprising one or more power level data portions, each of the power level data
10 portions being specific to each of one or more locations, the said power level data
11 portions being indicative of respective power level configurations of one or more
12 antenna amplifiers configured to adjust a power level of (e.g. amplify) signals to be
13 transmitted and/or received by the antenna; and a controller configured to: determine
14 (e.g. receive) a location of the antenna; select a power level data portion from the
15 said power level data taking into account the determined location of the antenna;
16 determine a power level configuration of the antenna amplifier(s) taking into account
17 the selected power level data portion; and configure the antenna amplifier(s) in
18 accordance with the said determined power level configuration.

19

20 A ninth aspect of the invention provides a non-transitory computer readable medium
21 tangibly embodying computer program code for causing a computer to control the
22 power level of signals to be transmitted and/or received by an antenna (typically a
23 steerable directional antenna) by: receiving location specific power level data
24 comprising one or more power level data portions, each of the power level data
25 portions being specific to a respective location; receiving a location of the antenna;
26 selecting a power level data portion from the location specific power level data taking
27 into account the received location of the antenna; determining a power level
28 configuration of the antenna amplifier(s) taking into account the said selected power
29 level data portion; and configuring the antenna amplifier(s) in accordance with the
30 said determined power level configuration.

31

32 A tenth aspect of the invention provides a method of generating location specific
33 power level data for one or more antenna amplifiers configured to adjust a power
34 level of (e.g. amplify) signals to be transmitted and/or received by an antenna
35 (typically a directional, steerable antenna), the location specific power level data
36 comprising one or more (typically two or more) power level data portions, each of the
37 power level data portions being specific to a respective (typically absolute) location,

1 the method comprising: providing the said antenna at a location; adjusting the signal
2 gains and/or the signal amplitudes provided by the said one or more antenna
3 amplifiers to thereby provide a wireless communications link between the antenna
4 and a terrestrial electromagnetic signal source meeting one or more link criteria; and
5 storing the said location together with a power level data portion related to or derived
6 from the said adjusted signal gains and/or signal amplitudes.

7

8 An eleventh aspect of the invention provides antenna apparatus comprising: an
9 antenna (typically a directional, steerable antenna); a memory; and a controller
10 comprising one or more computer processors, the controller being configured to:
11 determine a (typically absolute) location of the antenna; adjust signal gains and/or
12 signal amplitudes provided by one or more antenna amplifiers configured to adjust a
13 power level of (e.g. amplify) signals to be transmitted and/or received by the antenna
14 to thereby provide a wireless communications link between the antenna and a
15 terrestrial electromagnetic signal source meeting one or more link criteria; and store
16 in the memory the said location together with a power level data portion related to or
17 derived from the said adjusted signal gains and/or signal amplitudes.

18

19 The preferred and optional features of each aspect of the invention disclosed herein
20 are preferred and optional features of each other aspect of the invention to which they
21 are applicable. For the avoidance of doubt, the preferred and optional features of
22 each aspect of the invention are also preferred and optional features of all of the
23 other aspects of the invention, where applicable.

24

25 For the avoidance of doubt, in respect of the seventh to eleventh aspects of the
26 invention, it may be that the antenna amplifiers have respective gains which are
27 greater than unity, less than unity or unity. Accordingly, it may be that the one or
28 more antenna amplifiers comprise one or more signal boosters and/or one or more
29 signal attenuators. It may be that the one or more antenna amplifiers comprise a
30 plurality of antenna amplifiers. It may be that respective amplifiers of the said
31 plurality of antenna amplifiers have gains which are different from each other (e.g. in
32 the determined power level configuration).

33

34 Description of the Drawings

35

36 An example embodiment of the present invention will now be illustrated with
37 reference to the following Figures in which:

1

2 Figure 1 is a schematic diagram of a mobile wireless communication device having a
3 directional antenna pointing towards a terrestrial electromagnetic signal source;

4

5 Figure 2 is a similar schematic diagram to Figure 1, but with the device having
6 changed location as compared to the view of Figure 1 such that the directional
7 antenna points away from the terrestrial electromagnetic signal source;

8

9 Figure 3 is a similar schematic diagram to Figure 1, but with the device rotated as
10 compared to the view of Figure 1 such that the directional antenna points away from
11 the terrestrial electromagnetic signal source;

12

13 Figure 4 is a block diagram illustrating a controller of the device of Figures 1 to 3
14 configured to adjust the principal communication direction of the antenna to point at
15 the terrestrial electromagnetic signal source responsive to location;

16

17 Figure 5 is an illustration of a memory comprising a plurality of steering data portions,
18 each of which is associated with a respective location;

19

20 Figures 6 and 7 are schematic diagrams similar to Figures 2 and 3 respectively, but
21 with the principal communication direction of the directional antenna adjusted to point
22 towards the terrestrial electromagnetic signal source;

23

24 Figure 8 is a block diagram illustrating a beamforming algorithm for directionally
25 combining the signals from the elements of the antenna of Figures 1 to 3, 6 and 7;
26 and

27

28 Figure 9 is a schematic diagram of the device of Figures 1 to 3, 6 and 7 in
29 communication with a server computer.

30

31 Detailed Description of an Example Embodiment

32

33 Figure 1 is a schematic diagram of a human portable wireless communications
34 device 1 (such as a smartphone, tablet, laptop or wearable computer) having a
35 steerable directional antenna 2 comprising an array of antenna elements 4 in
36 communication with a controller 6 comprising a computer processor. The positions of
37 the antenna elements are fixed relative to a housing of the device 1. The antenna 2

1 is electronically steered by beamforming such that its principal communication
2 direction 7 is aligned with a terrestrial radio frequency electromagnetic signal source
3 8 (such as a base station of a cellular communications network, a Wi-fi router or a
4 Bluetooth beacon) with which the antenna 2 communicates (i.e. the antenna 2
5 transmits signals to and/or receives signals from the terrestrial electromagnetic signal
6 source 8). For typical directional antennas of this type, the majority of
7 electromagnetic signal power is transmitted within 60° of the principal communication
8 direction, and more preferably within 10° of the principal communication direction.

9

10 Figure 2 is a schematic diagram of the wireless communications device 1 having
11 changed location from that illustrated in Figure 1, the wireless communications
12 device 1 being closer to the (fixed location) electromagnetic signal source 8 in Figure
13 2 than in Figure 1. The antenna 2 of the wireless communications device 1 is
14 configured to have the same principal communication direction as in Figure 1.
15 Accordingly, as the device 1 has changed location, the principal communication
16 direction 7 of the antenna 2 no longer aligns with the electromagnetic signal source 8.
17 This reduces the quality of the wireless communications link between the antenna 2
18 and the signal source 8 (or even causes the said wireless communications link to be
19 dropped).

20

21 Similarly, Figure 3 is a schematic diagram of the wireless communications device 1
22 having been rotated from the position illustrated in Figure 1, but with the antenna
23 being configured to have the same principal communication direction as in Figure 1.
24 Again the principal communication direction of the antenna 2 no longer aligns with the
25 electromagnetic signal source 8. This reduces the quality of the wireless
26 communications link between the antenna 2 and the signal source 8 (or even causes
27 the said wireless communications link to be dropped).

28

29 Figure 4 illustrates transmitter circuitry of an RF front end 10 of the wireless
30 communications device 1, the transmitter circuitry comprising: the controller 6 in
31 communication with the antenna 2; a (typically analogue) power amplifier 12 which
32 provides amplified, modulated signals to the antenna 2 (for transmission to the
33 electromagnetic signal source 8) by amplifying modulated signals received from an
34 (typically analogue) RF modulator 14. The RF modulator 14 modulates a baseband
35 signal provided by (typically digital) baseband circuitry 16 (which signal is typically
36 converted into an analogue signal by a digital to analogue converter (DAC), not
37 shown, before it reaches the RF modulator) using a modulating signal from a local

1 oscillator (not shown). Further intermediate signal conditioning is typically provided,
2 for example band-pass filtering of the signal modulated by the RF modulator by a
3 tunable filter 18 for a specific frequency or dedicated channel to provide
4 optimum/desired performance.

5

6 The RF front end 10 further comprises receiver circuitry configured to process signals
7 received by the antenna 2 (e.g. in a receiver mode), but this is not shown in Figure 4.
8 For completeness, the RF receiver circuitry typically comprises a (typically analogue)
9 low noise amplifier configured to receive and amplify detected signals from the
10 antenna 2 and to provide the amplified signals to a (typically analogue) demodulator
11 (e.g. mixer) which receives the amplified signals as a first input and a demodulating
12 signal from a local oscillator as a second input. The demodulated signal is then
13 typically passed through an analogue to digital converter to the baseband circuitry 16.
14 Further intermediate signal conditioning circuitry is typically provided.

15

16 As illustrated above with respect to Figure 2, a change of location of the device 1
17 affects the spatial alignment between the principal communication direction of the
18 antenna 2 and the electromagnetic signal source 8, which can reduce the quality of
19 the wireless communications link between the antenna 2 and the electromagnetic
20 signal source 8. Accordingly, in order to maintain a wireless communications link
21 (and preferably a wireless communications link meeting one or more link quality
22 criteria) between the antenna 2 and the electromagnetic signal source 8, the
23 controller 6 is configured to adjust the principal communication direction of the
24 antenna 2 taking into account the location of the device 1. The controller 6 may be
25 configured to adjust the principal communication direction of the antenna 2
26 periodically, or responsive to a determination that the strength of signals received
27 from the electromagnetic signal source 8 or the link quality of the wireless
28 communications link between the antenna 2 and the electromagnetic signal source 8
29 do not meet one or more link criteria (e.g. particular bit rates, bit error rates, signal to
30 noise ratios). Measures of the link quality and signal strength are obtained from
31 baseband circuitry 27 (which is typically part of the baseband module 16) but may
32 alternatively (and preferably) be obtained by processing signals received (more
33 directly) from the analogue receiver circuitry of the RF front end (by way of an
34 analogue to digital converter), for example by measuring signal to noise ratio of the
35 received signals by comparing the received signals to a replica signal.

36

1 The controller 6 receives an estimate of the location of the wireless communications
2 device 1 (and therefore an estimate of the location of the antenna 2) from a location
3 sensor 20 (e.g. GPS location sensor, or any other suitable location sensor such as a
4 location sensor which uses the known positions of detectable electromagnetic signal
5 sources together with signals received from those signal sources to estimate the
6 position of the device, for example by triangulation) of the wireless communications
7 device 1. In addition, the controller 6 is configured to request and receive a user
8 profile 21 which is customised for a user of the device 1, and is at least in part derived
9 from usage of the device 1 by a user (e.g. a user registered to the device). The user
10 profile 21 may be provided on a memory of the device 1, but more typically the user
11 profile 21 is received by the controller 6 from a memory of one or more server
12 computers in data communication with the device 1.

13

14 As illustrated in Figure 5, the user profile 21 comprises location specific steering data
15 comprising a plurality of steering data portions 24, each of which is specific to a
16 respective absolute location 26. Each of the steering data portions 24 contains data
17 from which a principal communication direction of the antenna 2 can be derived in
18 order to provide, improve, or at least be closer to being able to provide a wireless
19 communications link between the antenna 2 and the electromagnetic signal source 8
20 when the device 1 is at the location 26 with which the steering data portion is
21 associated. It may be that more than one terrestrial electromagnetic signal source is
22 detectable by the device 1 at a said location, and it may be that steering data is
23 provided for each detectable electromagnetic signal source, or for the
24 electromagnetic signal source which provides the highest quality wireless
25 communications link, at that location. The locations 26 with which the steering
26 portions are associated may be respective single (two or three dimensional) points in
27 space (e.g. represented by location co-ordinates as shown in Figure 5) or loci of
28 points (e.g. represented by ranges of location co-ordinates).

29

30 The controller 6 selects a steering data portion 24 from the user profile 21 taking into
31 account the determined location of the device 1 and uses the selected steering data
32 portion 24 to determine an adjusted principal communication direction of the antenna.
33 The controller 6 then adjusts the principal communication direction of the antenna
34 based on the determined adjusted principal communication direction. There are
35 different types of steering data which can be provided to the controller in order to
36 determine the adjusted principal communication direction of the antenna 2 which is

1 required to provide a suitable wireless communications link. Some examples are
2 described as follows.

3

4 In one example, one or more or each of the steering data portions 24 provides
5 estimates of the locations of one or more electromagnetic signal sources which are
6 detectable by the device 1 at the location 26 associated with that steering data
7 portion 24 (which will be assumed to include the electromagnetic signal source 8).
8 The controller 6 determines the location of the device 1 from the location sensor 20,
9 selects a steering data portion 24 relating to that location, the steering data portion 24
10 comprising an estimated location of the electromagnetic signal source 8, and
11 calculates the adjusted principal communication direction of the antenna 2 taking into
12 account the estimated locations of both the device 1 and the electromagnetic signal
13 source 8 (e.g. in order to align the principal communication direction of the antenna 2
14 with the line of shortest distance to the electromagnetic signal source 8). The
15 controller 6 then adjusts the principal communication direction of the antenna 2
16 accordingly, thereby bringing the antenna 2 into communication with the
17 electromagnetic signal source 8 (if it wasn't already) or to thereby improve the quality
18 of the wireless communications link between them (as the case may be). This is
19 illustrated in Figure 6 which shows the misaligned principal communication direction
20 of Figure 2 as a dashed line, and the adjusted principal communication direction as a
21 solid line.

22

23 In another example, one or more or each of the steering data portions 24 provides an
24 estimate of a principal communication direction of the antenna 2 for providing a
25 wireless communications link between the antenna 2 and the electromagnetic signal
26 source 8 (or a different electromagnetic signal source, for example if it provides a
27 better wireless communications link with the antenna) at the location 26 with which it
28 is associated. The controller 6 determines the location of the antenna 2 from the
29 location sensor data and obtains the principal communication direction of the antenna
30 2 by selecting a steering data portion 24 associated with that location 26.

31

32 In another example, one or more or each of the steering data portions 24 provide
33 estimates of a direction of the electromagnetic signal source 8 relative to the device 1
34 at the location 26 with which it is associated. The controller 6 determines the location
35 of the device 1 and obtains the direction of the electromagnetic signal source 8
36 relative to the device 1 by selecting a steering data portion associated with that
37 location. The controller 6 then steers the antenna 2 in the said direction.

1

2 In another example one or more or each of the steering data portions 24 provide
3 configuration data (e.g. individually selectable beamforming coefficients and/or
4 weightings) which, when the antenna 2 is at the location 26 associated with that
5 steering data portion 24, can be used (e.g. directly) by the controller 6 to configure
6 antenna 2 so that its principal communication direction points towards the
7 electromagnetic signal source 8 (or to otherwise steer the antenna 2 into
8 communication with the electromagnetic signal source 8 (if it wasn't already) or to
9 improve the quality of the wireless communications link between them).

10

11 When the principal communication direction of the antenna 2 has been adjusted, the
12 controller 6 determines one or more parameters indicative of a quality of the wireless
13 communications link between the antenna 2 and the electromagnetic signal source 8,
14 for example from data obtained from baseband circuitry 27 of the device 1 or
15 alternatively (and preferably) by processing signals received (more directly) from the
16 analogue receiver circuitry as discussed above. The controller 6 then iteratively
17 adjusts (fine tunes) the principal communication direction 7 of the antenna 2 until the
18 wireless communications link between the antenna 2 and the electromagnetic signal
19 source 8 meets one or more link quality criteria (e.g. to achieve a particular bit rate,
20 bit error rate, signal to noise ratio, received signal strength etc).

21

22 In an alternative embodiment, rather than using a current location of the antenna 2 to
23 adjust the principal communication direction 7 of the antenna, it may be that the
24 controller 6 is configured to predict a future location of the antenna 2 and to adjust the
25 principal communication direction 7 of the antenna 2 in order to provide a wireless
26 communications link at the predicted future location. The controller 6 determines the
27 adjusted principal communication direction in advance of the device 1 reaching the
28 predicted future location. The controller 6 may then adjust the principal
29 communication direction accordingly responsive to a determination that the device 1
30 has reached the predicted future location, or alternatively the controller 6 may be
31 adjust the principal communication direction 7 of the antenna 2 in advance of the
32 device 1 reaching the predicted future location.

33

34 In order to predict a future position of the device 1, the controller 6 compares
35 successive estimates of the location of the device 1 from the location sensor 20. The
36 controller 6 also measures the speed and direction of movement of the device 1 from
37 the said successive estimates of the location of the device 1 from the location sensor,

1 and uses the said measured speed and direction of movement of the device 1
2 (together with its current location) to predict the said future position of the device 1.

3

4 In order to more accurately estimate the location of the antenna 2, and therefore
5 more accurately adjust the principal communication direction of the antenna 2 and
6 obtain a higher quality wireless communications link with the electromagnetic signal
7 source 8, it may be that the user profile 21 comprises data indicative of one or more
8 patterns of movement of the user associated with the user profile 21. For example,
9 the user profile 21 may comprise data indicative of one or more paths or routes
10 previously followed by the user (e.g. when carrying the said device 1 or when carrying
11 a different device which is also associated with the user). The controller 6
12 determines that the device 1 is following a said path or route by determining that the
13 device 1 occupies a location (or two or more successive locations) on the path or
14 route, or that the device 1 is approaching the said path or route. Time information
15 may also be taken into account (e.g. the path or route may be associated with one or
16 more times, and it may be determined that the device 1 is following the said path or
17 route responsive to a determination that a current time matches a time associated
18 with the said path or route). The controller 6 then predicts the said future location of
19 the device along the said path or route (or at a source or destination of the said path
20 or route). The principal communication direction of the antenna 2 is then adjusted on
21 the assumption that the antenna 2 is on the said path or route.

22

23 As an alternative to using the location sensor 20 (which may be unavailable or use
24 significant battery power), the location of the antenna 2 can be determined (together
25 with speed and direction) from sensor data provided by one or more sensors 37 of
26 the device 1 configured to detect movement of the device 1, such as one or more of:
27 accelerometer; magnetometer; compass; gyroscope. For example, such sensors
28 may be used to provide estimates of the location of the device 1 by pedometer dead
29 reckoning.

30

31 As illustrated in Figure 3, a change in the orientation of the antenna 2 (and thus the
32 orientation of the device 1) also affects the alignment between the antenna 2 and the
33 electromagnetic signal source 8. Accordingly, the controller 6 also receives
34 orientation information (typically pitch, yaw and roll of the device 1) from one or more
35 orientation sensors 28 of the device 1, and takes the orientation of the antenna 2 into
36 account (together with location as discussed above) when determining the adjusted
37 principal communication direction 7 of the device 1. This helps to provide, or improve

1 the quality of, a wireless communications link between the antenna 2 and the
2 electromagnetic signal source 8, as shown in Figure 7 which shows the misaligned
3 principal communication direction of Figure 3 as a dashed line, and the adjusted
4 principal communication direction as a solid line. The orientation sensors 28 typically
5 comprise any one or more of: accelerometer, gyroscope, compass, magnetometer.

6

7 The orientation of the antenna 2 can be taken into account by the controller 6 in
8 different ways. In one example, one or more or each of the steering data portions 24
9 is also associated with an orientation of the antenna 2 (e.g. by being associated with
10 an orientation of the device 1). The controller 6 then determines the orientation of the
11 antenna 2 (e.g. by determining the orientation of the device 1) and selects a steering
12 data portion associated with the determined location of the antenna 2 (or of the
13 device 1 comprising the antenna 2). The controller 6 then determines and
14 compensates for any difference in the determined orientation of the antenna 2 and
15 the orientation associated with the steering data portion 24 when determining the
16 adjusted principal communication direction 7 of the antenna 2.

17

18 In another example, the location specific steering data comprises steering data
19 portions 24 for each of a plurality of different orientations of the antenna 2 for each
20 location 26. In this case, the controller 6 selects a steering data portion 24
21 associated with both the determined location of the antenna 2 and its received
22 orientation, and uses the selected steering data portion 24 to determine the adjusted
23 principal communication direction 7 of the antenna 2.

24

25 In order to take into account other factors which may affect the optimum principal
26 communication direction of the antenna 2 in relation to the electromagnetic signal
27 source 8, the controller 6 receives sensor data from a plurality of sensors, including
28 one or more proximity sensors 30, pressure sensors 32 and temperature sensors 34.
29 The controller 6 then also (e.g. in addition to location, and typically the orientation of
30 the device 1) takes the sensor data into account when determining the adjusted
31 principal communication direction of the antenna 2.

32

33 When a user is in close proximity to the antenna 2, a higher quality wireless
34 communications link may be achieved with the electromagnetic signal source 8 if the
35 principal communication direction of the antenna 2 points away from the user, even if
36 that means also directing the antenna 2 away from the electromagnetic signal source
37 8 (e.g. to instead align the antenna 2 with a reflected signal propagation path to or

1 from the signal source 8). Accordingly, proximity sensor data can be useful when
2 determining the adjusted principal communication direction of the antenna 2. In one
3 example, different steering data portions 24 can be provided in the user profile 21 for
4 situations in which the user is in close proximity to the antenna 2 and for situations in
5 which the user is not in close proximity to the antenna. In this case, the controller 6
6 selects one of the former steering data portions 24 responsive to a determination
7 from the proximity sensor data that the user is in close proximity to the antenna 2 and
8 one of the latter steering data portions 24 responsive to a determination from the
9 proximity sensor data that the user is not in close proximity to the antenna 2.

10

11 Additionally or alternatively, the controller may determine from proximity sensor data
12 the relative direction of one or more (typically external) objects in close proximity to
13 the antenna. For example, it may be that the proximity sensor uses one or more
14 directional electromagnetic signal sources (e.g. infrared LED) to transmit
15 electromagnetic radiation in a given direction, and one or more directional
16 photodetectors to detect reflected radiation from one or more objects in close
17 proximity to the antenna. When an object is detected, it can be deduced that the
18 direction of the said object relative to the antenna corresponds with the transmission
19 direction of the electromagnetic signal source. This direction information can be
20 taken into account when determining the adjusted the principal communication
21 direction of the antenna 2 (e.g. the antenna radiation may be directed away from the
22 direction of the object).

23

24 The said one or more pressure and one or more temperature sensors 32, 34 are
25 typically provided on (or at least in communication with) an external surface of the
26 housing of the device 1. By detecting pressure and temperature at one or more
27 portions of the external surface of the housing, the way in which the user is holding
28 the device 1 (or indeed whether the device 1 is being held at all) can be determined.
29 The way in which the user is holding the device (e.g. positions of the user's fingers on
30 the external surface of the housing of the device) may be indicative of an orientation
31 of the device and/or a proximity of the user to the device. The controller 6 therefore
32 takes sensor data from the pressure and temperature sensors into account when
33 determining the adjusted principal communication direction of the antenna 2. For
34 example, it may be that each of one or more steering data portions 24 is associated
35 with a condition that selected temperature sensors 34 of the device 1 detect
36 temperatures greater than a threshold temperature (which may indicate that the
37 device is being held in a particular way, from which an orientation of the antenna 2

1 can be deduced) and the steering data portion 24 associated with that condition
2 provides antenna configuration data suitable for adjusting the principal
3 communication direction 7 to direct radiation to (or receive radiation from) the
4 electromagnetic signal source 8 when the antenna 2 is at that orientation.

5

6 Another parameter which the controller 6 takes into account when adjusting the
7 principal communication direction of the antenna is usage mode data indicative of a
8 usage mode of the device 1, such as: voice call mode, video call mode, browsing
9 internet mode, watching video mode, download mode, upload mode. The controller 6
10 receives usage mode data indicative of a usage mode of the device 1 from a usage
11 mode sensor of the operating system 36. The usage mode of the device 1 is typically
12 indicative of the orientation of the device which, as shown in Figure 3, affects the
13 direction of the electromagnetic signal source relative to the antenna. The usage
14 mode of the device can also be used to determine a proximity of the user to the
15 antenna 2. For example, the controller 6 may deduce that a user is in close proximity
16 to the antenna 2 when the device 1 is in the voice call usage mode. Thus, by taking
17 the usage mode of the device 1 into account, the controller 6 can determine a more
18 optimum adjusted principal communication direction of the antenna 2.

19

20 The controller 6 may also be configured to take into account whether one or more
21 device peripherals are being used (or whether one or more device peripherals are
22 coupled to the device by way of one or more ports) when deducing the proximity of a
23 user to the antenna 2. In the voice call usage mode example, the controller may be
24 configured to deduce that a user is in close proximity to the device responsive to a
25 determination (e.g. from a headphone sensor) that no headphones are plugged in to
26 the device 1 (indicating that hands free is not being used) and that a loudspeaker of
27 the device 1 is switched off (indicating that speaker phone is not being used).

28

29 The usage mode of the device 1 can be taken into account by the controller 6 in
30 different ways. In one example, one or more or each of the steering data portions 24
31 are also associated with a usage mode of the device 1, and the controller 6 is
32 configured to select a steering data portion 24 associated with the determined usage
33 mode of the device 1. In another example, the user profile 21 comprises usage mode
34 data which is indicative of one or more parameters specific to (and typically
35 associated with) each of one or more usage modes. For example, the usage mode
36 specific parameters may comprise (for each of one or more usage modes): an
37 orientation of the device; a proximity of a user to the device; a location of the user

1 relative to the antenna; an antenna steering configuration or direction. One or more
2 of the usage mode specific parameters may be location specific. For example, the
3 usage mode specific parameters may comprise a location of an electromagnetic
4 signal source (e.g. wifi access point or cellular communication system base station)
5 with which the antenna communicates in a particular usage mode when the antenna
6 is at a particular location. The usage mode parameters are also typically specific to a
7 or the user of the device (indeed, the said parameters are typically derived from prior
8 use of the antenna by the user). The controller 6 takes the said parameters
9 associated with a usage mode into account when determining the adjusted principal
10 communication direction of the antenna 2, responsive to a determination that the
11 device 1 is being used in the said usage mode.

12

13 It will be understood that the wireless communications device 1 may be configured to
14 communicate with a plurality of electromagnetic signal sources of different types,
15 such as a Wi-Fi access point, a Bluetooth beacon and a cellular network base station.
16 It may be that the user profile 21 stores location specific steering data for one
17 (typically two) or more types of electromagnetic signal source. In this case, the
18 steering data portions 24 are typically each associated with a type of communication
19 and the controller 6 is configured to receive a communications type which the
20 antenna 2 is trying to perform (e.g. from the Media Access Control (MAC) layer of the
21 baseband circuitry 16) and to select a steering data portion 24 associated with the
22 received communications type.

23

24 The controller 6 is also typically configured to receive frequency channel data from
25 the baseband circuitry 27 indicative of a frequency channel on which the antenna is
26 communicating with the electromagnetic signal source 8. The frequency channel
27 data can be used to select steering data from the user profile 21 which is associated
28 with the said frequency channel on which the antenna is communicating. For
29 example, the user profile 21 may comprise data specifying a particular steering
30 configuration for the antenna 2 when it communicates on a particular WiFi frequency
31 channel at a particular location which reduces interference with other WiFi
32 communications (e.g. on that or an adjacent channel) typically occurring at that
33 location.

34

35 It may be that the power amplifier 12 and/or the low noise amplifier of the RF front
36 end have tuneable frequency responses. It may be that the controller 6 is also
37 configured to use the frequency channel data to adjust the frequency response of the

1 power amplifier 12 and/or the low noise amplifier (not shown) to thereby improve the
2 performance of the amplifier at one or more frequencies of the said frequency
3 channel. This is particularly important when the frequency channel is at the periphery
4 of a frequency range comprising all available frequency channels for a particular
5 wireless communications type, typically because by default the frequency response
6 of the amplifier is tuned for peak performance at the centre of the said frequency
7 range. Accordingly, by adjusting the frequency response of the amplifier taking into
8 account the said frequency channel, the quality of the communications link between
9 the antenna 2 and the electromagnetic signal source 8 is improved. The frequency
10 channel data can also be used to tune the frequency response of the filter 18.

11

12 As indicated above, the principal communication direction of the antenna 2 is typically
13 adjusted by beamforming (although it will be appreciated that an alternative steerable
14 directional antenna, such as a mechanically rotatable directional antenna or a sector
15 antenna could instead be employed). Beamforming for a received signal is illustrated
16 in Figure 8, but it will be understood that beamforming for a transmitted signal
17 operates on similar principles. The antenna elements 4a-4f are each in
18 communication with a variable phase shifter 40 which is configured by the controller 6
19 to apply a selectable phase shift to signals received from the respective antenna
20 element. Next, the phase shifted signal is input to a signal weighting algorithm 42
21 which applies a selectable weighting to each of the respective phase shifted signals.
22 Next, the weighted, phase shifted signals are summed together by a summing
23 algorithm 43. By controlling the phase shifts and weightings applied to the signals
24 received by each antenna element 4a-4f (which are typically different from each
25 other), the controller 6 controls the principal communication direction 7 of the antenna
26 2.

27

28 The weightings applied by the weighting algorithm 42 also determine the
29 amplification of signals provided to (for transmission by), and received by, the
30 antenna 2. Accordingly, the weightings applied by the weighting algorithm 42 can be
31 used to adjust the amplification of signals provided to (for transmission by), and
32 received by, the antenna 2 (and so the weighting algorithm can be considered to be
33 an antenna amplifier configured to amplify signals to be transmitted or received by
34 the antenna). In the event that a mechanically rotatable or sector antenna is
35 provided, it may be that an additional antenna amplifier (typically separate from the
36 power amplifier 12 and the low noise amplifier of the RF front end) is provided which
37 amplifies signals provided to (for transmission by), and received by, the antenna 2.

1 The controller 6 is configured to control the level of amplification provided to the
2 signals provided to (for transmission by), and received by, the antenna 2 by way of
3 the individually selectable beamforming weightings or by way of the gain of the
4 additional antenna amplifier as the case may be.

5

6 The user profile 21 stores power level data indicative of respective power level
7 configurations of the antenna amplifiers (e.g. which enable the antenna to
8 communicate with the terrestrial electromagnetic signal source from the locations
9 with which they are associated in the user profile 21), such as the beamforming
10 weightings or gains of the additional amplifier and/or the power amplifier and/or the
11 low noise amplifier. The controller 6 selects power level data from the user profile
12 21 responsive to the determined location of the device 1, and determines a signal
13 gain and/or an amplification level to be applied (or signal amplitudes to be provided)
14 by the beamforming weightings or by the additional antenna amplifier and/or the
15 power amplifier and/or the low noise amplifier taking into account the selected power
16 level data. This helps to reduce unproductive battery power consumption on the
17 device by, for example, unnecessarily over-amplifying the signals for transmission by
18 the antenna 2.

19

20 The controller 6 may also take into account sensor data received from one or more of
21 the sensors of the device 1 when determining the signal gain and/or amplification
22 level and/or signal amplitude provided by the antenna amplifiers. For example,
23 sensor data from the proximity sensor 30 may indicate that a user is in close
24 proximity to the antenna and that, as a result, the adjusted principal communication
25 direction does not point directly at the terrestrial electromagnetic signal source 8.
26 Accordingly, it may be necessary to increase the power level to compensate. The
27 signal gain and/or amplification level and/or signal amplitude provided by one or more
28 or each of the antenna amplifiers may then be iteratively adjusted to meet a or the
29 target quality of wireless communications link between the antenna 2 and the said
30 terrestrial electromagnetic signal source 8. Typically, the said power level data is
31 derived from prior usage of the antenna 2 by the user.

32

33 In another example, usage mode data from the usage mode sensor may indicate that
34 the antenna 2 is required to download a large quantity of data and so requires a
35 wireless communications link to be provided which permits high data transfer rates.
36 In this case, the controller 6 takes into account the usage mode data and provides an
37 increased level of amplification, e.g. by adjusting the beamforming weightings or the

1 gain of the additional antenna amplifier (and/or by increasing the amplification of the
2 low noise amplifier for example) accordingly in order to provide the required high data
3 transfer rate.

4

5 Where the controller 6 controls the level of amplification provided by the power
6 amplifier 12 as well as the beamforming weightings or the gain of the additional
7 amplifier, the controller 6 typically controls the level of amplification provided by the
8 power amplifier 12 taking into account the amplification provided by the beamforming
9 weightings or the gain of the additional antenna amplifier.

10

11 Similarly, where the controller 6 controls the level of amplification provided by the low
12 noise amplifier as well as the beamforming weightings or the gain of the additional
13 amplifier, the controller 6 typically controls the level of amplification provided by the
14 low noise amplifier taking into account the amplification provided by the beamforming
15 weightings or the gain of the additional antenna amplifier.

16

17 In order to generate the user profile 21, to dynamically update the user profile over
18 time, and of course to communicate with the electromagnetic signal source when the
19 antenna occupies a location in respect of which the user profile lacks (suitably
20 accurate) steering data, the controller 6 adjusts the principal communication direction
21 of the antenna across a range of principal communication directions until a (typically
22 radio frequency) wireless communications link between the antenna and a terrestrial
23 electromagnetic signal source is obtained which meets one or more link criteria. For
24 example, the link criteria may comprise: that a wireless communications link has
25 been established between the antenna 2 and the terrestrial electromagnetic signal
26 source (e.g. when previously there was no such link); that a wireless communications
27 link has been established between the antenna 2 and the terrestrial electromagnetic
28 signal source 8 having a bit rate exceeding a predetermined threshold; that a wireless
29 communications link has been established between the antenna 2 and the terrestrial
30 electromagnetic signal source 8 having a bit error rate below a predetermined
31 threshold; that a wireless communications link has been established between the
32 antenna and the terrestrial electromagnetic signal source having a signal to noise
33 ratio above a predetermined threshold; or that a wireless communications link has
34 been established between the antenna and the terrestrial electromagnetic signal
35 source having a received signal strength greater than a predetermined threshold.

36

1 To assist in this process, the controller 6 may be configured to obtain assistance data
2 from a general database 45 (which may be provided on the memory of the device, the
3 memory of one or more server computers with which the device can communicate or
4 a combination of a memory of the device and a memory of one or more server
5 computers with which the device can communicate). The assistance data typically
6 comprises locations of electromagnetic signal sources, which are typically identified
7 in the general database 45 by identifiers such as MAC addresses. When the antenna
8 2 detects electromagnetic signals from an electromagnetic signal source, it obtains
9 the identifier of the electromagnetic signal source from the detected signals and uses
10 the identifier to interrogate the general database 45 to determine a location of the
11 electromagnetic signal source. The controller 6 then uses this information (together
12 with any other available data such as orientation of the device, sensor data, usage
13 mode data etc as discussed herein above) to calculate the adjusted principal
14 communication direction and to adjust the principal communication direction of the
15 antenna in accordance with the adjusted principal communication direction. This is
16 typically a slower process and is less power efficient than obtaining steering data
17 from the user profile 21, but is typically quicker and more power efficient than
18 performing a full scan across all possible principal communication directions of the
19 antenna to determine the optimum adjusted principal communication direction.

20

21 The location of the device 1 when the said wireless communications link was
22 achieved (received from location sensor 20) is stored in a memory of the device
23 together with steering data related to, or derived from, the said adjusted principal
24 communication direction and an identifier (e.g. MAC address) of the electromagnetic
25 signal source 8. As discussed above, the steering data may comprise any of, for
26 example: an estimated location of the said terrestrial electromagnetic signal source 8;
27 antenna configuration data representing the said adjusted principal communication
28 direction of the antenna; and data representing the adjusted principal communication
29 direction.

30

31 The controller 6 also stores data representing the said orientation of the antenna 2
32 (determined from the said orientation sensor of the device) together with said steering
33 data and location. The controller 6 may also store: a usage mode of the device 1; a
34 frequency channel of the wireless communications link; and/or a communications
35 type of the wireless communications link; a quality of the said wireless
36 communications link; and/or the strength of signals received from the electromagnetic
37 signal source. The controller 6 may also store power level data indicative of

1 respective power level configurations of one or more antenna amplifiers configured to
2 adjust a power level of (e.g. amplify) signals to be transmitted and/or received by the
3 antenna (e.g. which enable the antenna to communicate with the terrestrial
4 electromagnetic signal source from the said locations). It will be understood that the
5 respective antenna amplifiers may have gains which are greater than unity, less than
6 unity or unity. Accordingly, the respective antenna amplifiers may comprise one or
7 more signal boosters and/or one or more signal attenuators. For example, the power
8 level data may comprise the beamforming weightings or the gain of the additional
9 antenna amplifier (where provided). Additionally or alternatively the power level data
10 may comprise the gain of the power amplifier 12 and/or the gain of the low noise
11 amplifier when the link criteria were met.

12

13 As illustrated in Figure 9, the controller 6 initially stores steering data (and any
14 additional data - e.g. orientation data, proximity data, usage mode data, power level
15 data, frequency channel data, communications type data, data indicating the quality
16 of the wireless communications link with or received signal strength from the
17 electromagnetic signal source) on its local memory and then uploads the steering
18 data (and any additional data) stored on its local memory to a server computer 50
19 over a communications link 52, typically as a batch update in which a plurality of sets
20 of steering data (and associated additional data) are uploaded to the server 50.
21 Before uploading data to the server computer 50, a check may be performed by the
22 controller 6 as to whether a battery level of the device is above a predetermined
23 threshold and, if so, to proceed with the upload. If the battery power is below the
24 threshold, it may be that the controller 6 does not upload the data to the server 50, at
25 least until the battery level is again above the threshold. The battery level data may
26 be determined from an operating system 36 running on the device 1.

27

28 By generating the user profile 21 from usage of the antenna 2 by the user, it is
29 ensured that the steering data provided in the user profile 21 is specific to that user.
30 Accordingly, only steering data relevant to the user is stored, and the steering data
31 selected to adjust the principal communication direction of the antenna in use is
32 typically more accurate for that user.

33

34 Again to preserve battery life, when the principal communication direction is being
35 iteratively adjusted to optimise the quality of the wireless communications link
36 between the antenna 2 and the electromagnetic signal source 8, it may be that the
37 controller is configured to adjust the principal communication direction of the antenna

1 across only a subset of a possible range of principal communication directions of the
2 antenna responsive to a determination that the battery level is below a or the
3 predetermined threshold.

4

5 It will be understood that the sensors may be implemented in software (e.g. a usage
6 mode sensor may be a signal from an operating system running on the device
7 indicating whether the device is being used to make a call), hardware or in a
8 combination of hardware and software.

9

10 It may be that the controller adjusts the principal communication direction of the
11 antenna responsive to a detected movement of the device (e.g. change of orientation
12 or location). Alternatively, it may be that the controller 6 is configured to adjust the
13 principal communication direction 7 at regular time intervals, using the most recently
14 estimated location of the device 1 from the location sensor 20 in each case.

15

16 Further modifications and variations may be made within the scope of the invention
17 herein disclosed.

18

19 For example, although (for simplicity) Figures 2, 3, 6 and 7 and their associated
20 descriptions may imply that the optimum principal communication direction of the
21 antenna is always to align the principal communication direction with a line of sight to
22 the electromagnetic signal source 8, it will be understood that in some circumstances
23 the optimum principal communication direction of the antenna is along a path (e.g.
24 comprising one or more signal reflections) which does not lie on a line of sight to the
25 electromagnetic signal source 8 from the antenna 2. In practice the steering data
26 portions 24 provided in the user profile 21 store data from which the determined
27 optimum principal communication direction can be derived, whether it lies on a line of
28 sight to the electromagnetic signal source or not.

29

30 In another example, although the above description states that the user profile 21 is
31 received by the controller 6, it may be that only a portion of the user profile 21 is
32 received by the controller 6. It may be that the said portion of the user profile 21 is
33 selected on the basis of the determined location of the device 1. For example, the
34 said portion of the user profile 21 may be a portion of the user profile 21 relating to a
35 geographical region comprising the determined location of the device 1. In this case,
36 it may be that the said steering data portion is selected from the said portion of the
37 user profile 21.

1

2 In other embodiments, it may be that the location specific steering data is obtained
3 from a database of location specific steering data (which may not be user specific).

4 In this case, rather than selecting the steering data portion from the user profile 21,
5 the controller 6 may be configured to receive the database of location specific
6 steering data, or a portion thereof (e.g. selected on the basis of the determined
7 location of the device 1, such as by selecting a portion of the database specific to a
8 geographical region comprising the determined location of the device), and to select
9 the said steering data portion from the said database or portion thereof.

10

11 Various embodiments of the invention are described by the numbered Clauses
12 below:

13

14 1. A method of adjusting a principal communication direction of a steerable
15 directional antenna for communicating with a terrestrial electromagnetic signal
16 source, the method comprising: providing location specific steering data
17 comprising one or more steering data portions, each of the steering data
18 portions being specific to a respective location; determining a location of the
19 steerable directional antenna; selecting a steering data portion from the
20 location specific steering data taking into account the determined location of
21 the antenna; determining an adjusted principal communication direction of the
22 steerable directional antenna taking into account the said selected steering
23 data portion; and adjusting the principal communication direction of the
24 steerable directional antenna in accordance with the said adjusted principal
25 communication direction.

26

27 2. The method according to clause 1 wherein one or more or each of the
28 steering data portions are derived from prior usage of the antenna by a user.

29

30 3. The method according to clause 1 or clause 2 wherein the said location
31 specific steering data is provided in a user profile which is customised for a or
32 the said user.

33

34 4. The method according to any one preceding clause further comprising
35 selecting a said steering data portion from the location specific steering data
36 and/or determining the said adjusted principal communication direction of the

- 1 steerable directional antenna taking into account sensor data from one or
2 more sensors.
3
- 4 5. The method according to any one preceding clause further comprising:
5 determining an orientation of the antenna; and selecting the said steering data
6 portion from the location specific steering data taking into account the
7 determined orientation of the antenna.
8
- 9 6. The method according to any one preceding clause further comprising:
10 determining an orientation of the antenna; and determining the said adjusted
11 principal communication direction of the steerable directional antenna taking
12 into account the determined orientation of the antenna.
13
- 14 7. The method according to any one preceding clause further comprising:
15 selecting the said steering data portion from the location specific steering
16 data, and/or determining the said adjusted principal communication direction
17 of the steerable directional antenna, taking into account sensor data from one
18 or more proximity sensors.
19
- 20 8. The method according to any one preceding clause further comprising:
21 selecting the said steering data portion from the location specific steering data
22 and/or determining the said adjusted principal communication direction of the
23 steerable directional antenna taking into account sensor data from one or
24 more pressure sensors and/or one or more temperature sensors.
25
- 26 9. The method according to any one preceding clause further comprising:
27 determining a usage mode of a or the device comprising the antenna; and
28 selecting a steering data portion from the location specific steering data taking
29 into account the determined usage mode of the device.
30
- 31 10. The method according to any one preceding clause further comprising:
32 determining a usage mode of a or the device comprising the antenna; and
33 determining the adjusted principal communication direction of the steerable
34 directional antenna taking into account the determined usage mode of the
35 device.
36

- 1 11. The method according to any one preceding clause further comprising:
2 detecting motion of the antenna; and selecting the said steering data portion
3 from the location specific steering data taking into account the detected
4 motion of the antenna.
5
- 6 12. The method according to any one preceding clause further comprising:
7 detecting motion of the antenna; and determining the adjusted principal
8 communication direction of the steerable directional antenna taking into
9 account the detected motion of the antenna.
10
- 11 13. The method according to any one preceding clause further comprising:
12 providing location specific power level data comprising one or more power
13 level data portions, each of the power level data portions being specific to
14 each of one or more locations, the said power level data portions being
15 indicative of respective power level configurations of one or more antenna
16 amplifiers configured to amplify signals to be transmitted or received by the
17 antenna; selecting a power level data portion from the said power level data
18 taking into account the determined location of the device; determining a power
19 level configuration of the antenna amplifier(s) taking into account the selected
20 power level data portion; and configuring the antenna amplifier(s) in
21 accordance with the said determined power level configuration.
22
- 23 14. The method according to any one preceding clause further comprising:
24 selecting the said steering data portion taking into account a type of
25 communication performed by the antenna and/or by the terrestrial
26 electromagnetic signal source.
27
- 28 15. Steerable directional antenna apparatus comprising:
29
30 a steerable directional antenna for communicating with a terrestrial
31 electromagnetic signal source;
32
33 a memory comprising location specific steering data comprising one or
34 more steering data portions, each steering data portion being specific to a
35 respective location; and
36

- 1 a controller comprising one or more computer processors, the controller
2 being configured to: determine a location of the steerable directional
3 antenna; select a steering data portion from the location specific steering
4 data taking into account the determined location of the antenna; determine
5 an adjusted principal communication direction of the steerable directional
6 antenna taking into account the said selected steering data portion; and
7 adjust the principal communication direction of the steerable directional
8 antenna in accordance with the said adjusted principal communication
9 direction.
- 10
- 11 16. A method of generating location specific steering data for a steerable
12 directional antenna, the location specific steering data comprising one or more
13 steering data portions, each of the steering data portions being specific to a
14 respective location, the method comprising: providing the said steerable
15 directional antenna at a location; adjusting a principal communication
16 direction of the antenna to thereby provide a wireless communications link
17 between the antenna and a terrestrial electromagnetic signal source meeting
18 one or more link criteria; and storing the said location together with a steering
19 data portion related to, or derived from, the said adjusted principal
20 communication direction.
- 21
- 22 17. The method according to clause 16 wherein the said steering data portion
23 comprises any one or more of: an estimated location of the said terrestrial
24 electromagnetic signal source; antenna configuration data representing the
25 said adjusted principal communication direction of the antenna; and data
26 representing the adjusted principal communication direction.
- 27
- 28 18. The method according to clause 16 or clause 17 further comprising:
29 determining an orientation of the antenna; and storing data representing the
30 said orientation of the antenna together with said steering data portion and
31 location.
- 32
- 33 19. The method according to any one of clauses 16 to 18 further comprising:
34 determining a usage mode of a device comprising the antenna; and storing
35 usage mode data representing the said usage mode together with said
36 steering data portion and location.
- 37

- 1 20. Steerable directional antenna apparatus comprising: a steerable directional
2 antenna; a memory; and a controller comprising one or more computer
3 processors, the controller being configured to: determine a location of the
4 antenna; adjust a principal communication direction of the antenna to thereby
5 provide a wireless communications link between the antenna and a terrestrial
6 electromagnetic signal source meeting one or more link criteria; and store in
7 the memory the said location together with a steering data portion related to,
8 or derived from, the said adjusted principal communication direction.
9
- 10 21. A non-transitory computer readable medium tangibly embodying computer
11 program code for causing a computer to adjust a principal communication
12 direction of a steerable directional antenna for communicating with a
13 terrestrial electromagnetic signal source by: receiving location specific
14 steering data comprising one or more steering data portions, each of the
15 steering data portions being specific to a respective location; receiving a
16 location of the steerable directional antenna; selecting a steering data portion
17 from the location specific steering data taking into account the received
18 location of the antenna; determining an adjusted principal communication
19 direction of the steerable directional antenna taking into account the said
20 selected steering data portion; and adjusting the principal communication
21 direction of the steerable directional antenna in accordance with the said
22 adjusted principal communication direction.
23
- 24 22. A non-transitory computer readable medium tangibly embodying computer
25 program code for causing a computer to generate location specific steering
26 data for a steerable directional antenna, the location specific steering data
27 comprising one or more steering data portions, each of the steering data
28 portions being specific to a respective location, by: receiving a location of the
29 antenna; adjusting a principal communication direction of the antenna to
30 thereby provide a wireless communications link between the antenna and a
31 terrestrial electromagnetic signal source meeting one or more link criteria; and
32 storing the said location together with a steering data portion related to, or
33 derived from, the said adjusted principal communication direction.
34
35

1 Claims

2

- 3 1. A method of adjusting a principal communication direction of a steerable
4 directional antenna for communicating with a terrestrial electromagnetic signal
5 source, the method comprising: providing location specific steering data
6 comprising one or more steering data portions, each of the steering data
7 portions being specific to a respective location; determining a location of the
8 steerable directional antenna; selecting a steering data portion from the
9 location specific steering data taking into account the determined location of
10 the antenna; determining an adjusted principal communication direction of the
11 steerable directional antenna taking into account the said selected steering
12 data portion; and adjusting the principal communication direction of the
13 steerable directional antenna in accordance with the said adjusted principal
14 communication direction, wherein the method further comprises providing
15 location specific power level data comprising one or more power level data
16 portions, each of the power level data portions being specific to each of one or
17 more locations, the said power level data portions being indicative of
18 respective power level configurations of one or more antenna amplifiers
19 configured to adjust a power level of signals to be transmitted or received by
20 the antenna; selecting a power level data portion from the said power level
21 data taking into account the determined location of the antenna; determining a
22 power level configuration of the antenna amplifier(s) taking into account the
23 selected power level data portion; and configuring the antenna amplifier(s) in
24 accordance with the said determined power level configuration.
25
- 26 2. The method according to claim 1 wherein one or more or each of the steering
27 data portions are derived from prior usage of the antenna by a user.
28
- 29 3. The method according to claim 1 or claim 2 wherein the said location specific
30 steering data is provided in a user profile which is customised for a or the said
31 user.
32
- 33 4. The method according to any one preceding claim further comprising
34 selecting a said steering data portion from the location specific steering data
35 and/or determining the said adjusted principal communication direction of the
36 steerable directional antenna taking into account sensor data from one or
37 more sensors.

- 1
- 2 5. The method according to any one preceding claim further comprising:
3 determining an orientation of the antenna; and selecting the said steering data
4 portion from the location specific steering data taking into account the
5 determined orientation of the antenna.
6
- 7 6. The method according to any one preceding claim further comprising:
8 determining an orientation of the antenna; and determining the said adjusted
9 principal communication direction of the steerable directional antenna taking
10 into account the determined orientation of the antenna.
11
- 12 7. The method according to any one preceding claim further comprising:
13 selecting the said steering data portion from the location specific steering
14 data, and/or determining the said adjusted principal communication direction
15 of the steerable directional antenna, taking into account sensor data from one
16 or more proximity sensors.
17
- 18 8. The method according to any one preceding claim further comprising:
19 selecting the said steering data portion from the location specific steering data
20 and/or determining the said adjusted principal communication direction of the
21 steerable directional antenna taking into account sensor data from one or
22 more pressure sensors and/or one or more temperature sensors.
23
- 24 9. The method according to any one preceding claim further comprising:
25 determining a usage mode of a or the device comprising the antenna; and
26 selecting a steering data portion from the location specific steering data taking
27 into account the determined usage mode of the device.
28
- 29 10. The method according to any one preceding claim further comprising:
30 determining a usage mode of a or the device comprising the antenna; and
31 determining the adjusted principal communication direction of the steerable
32 directional antenna taking into account the determined usage mode of the
33 device.
34
- 35 11. The method according to any one preceding claim further comprising:
36 detecting motion of the antenna; and selecting the said steering data portion

- 1 from the location specific steering data taking into account the detected
2 motion of the antenna.
3
- 4 12. The method according to any one preceding claim further comprising:
5 detecting motion of the antenna; and determining the adjusted principal
6 communication direction of the steerable directional antenna taking into
7 account the detected motion of the antenna.
8
- 9 13. The method according to any one preceding claim further comprising:
10 selecting the said steering data portion taking into account a type of
11 communication performed by the antenna and/or by the terrestrial
12 electromagnetic signal source.
13
- 14 14. The method according to any one of claims 1 to 13 wherein the selected
15 steering data portion is specific to a future location of the antenna predicted
16 taking into account the said determined location of the antenna.
17
- 18 15. The method according to any one of claims 1 to 14 further comprising:
19 determining a frequency channel on which the antenna is communicating with
20 the electromagnetic signal source; and adjusting a frequency response of one
21 or more antenna amplifiers configured to amplify signals to be transmitted
22 and/or received by the antenna taking into account the said frequency
23 channel.
24
- 25 16. The method according to any one of claims 1 to 15 wherein each said steering
26 data portion is associated with an expected link quality of a wireless
27 communications link between the antenna and the electromagnetic signal
28 source.
29
- 30 17. The method according to claim 16 wherein the method further comprises:
31 comparing a current link quality of a wireless link between the said antenna
32 and the electromagnetic signal source with the said expected link quality; and
33 selecting the said steering data portion responsive to a determination that the
34 expected link quality is greater than the said current link quality.
35
- 36 18. The method according to any one preceding claim wherein the said one or
37 more antenna amplifiers configured to adjust a power level of signals to be

1 transmitted or received by the antenna are configured to amplify signals to be
2 transmitted or received by the antenna.

3

4 19. Steerable directional antenna apparatus comprising:

5

6 a steerable directional antenna for communicating with a terrestrial
7 electromagnetic signal source;

8

9 a memory comprising location specific steering data comprising one or
10 more steering data portions, each steering data portion being specific to a
11 respective location; and

12

13 a controller comprising one or more computer processors, the controller
14 being configured to: determine a location of the steerable directional
15 antenna; select a steering data portion from the location specific steering
16 data taking into account the determined location of the antenna; determine
17 an adjusted principal communication direction of the steerable directional
18 antenna taking into account the said selected steering data portion; and
19 adjust the principal communication direction of the steerable directional
20 antenna in accordance with the said adjusted principal communication
21 direction,

22

23 wherein the memory further comprises location specific power level data
24 comprising one or more power level data portions, each of the power level
25 data portions being specific to each of one or more locations, the said
26 power level data portions being indicative of respective power level
27 configurations of one or more antenna amplifiers configured to adjust a
28 power level of signals to be transmitted and/or received by the antenna;

29

30 and wherein the controller is further configured to: select a power level
31 data portion from the said power level data taking into account the
32 determined location of the antenna; determine a power level configuration
33 of the antenna amplifier(s) taking into account the selected power level
34 data portion; and configure the antenna amplifier(s) in accordance with the
35 said determined power level configuration.

36

- 1 20. Steerable directional antenna apparatus according to claim 19 wherein the
2 selected steering data portion is specific to a future location of the antenna
3 predicted taking into account the said determined location of the antenna.
4
- 5 21. Steerable directional antenna apparatus according to claim 19 or claim 20
6 wherein the controller is configured: to determine a frequency channel on
7 which the antenna is communicating with the electromagnetic signal source;
8 and to adjust a frequency response of one or more antenna amplifiers
9 configured to amplify signals to be transmitted and/or received by the antenna
10 taking into account the said frequency channel.
11
- 12 22. Steerable directional antenna apparatus according to any one of claims 19 to
13 21 wherein each said steering data portion is associated with an expected link
14 quality of a wireless communications link between the antenna and the
15 electromagnetic signal source.
16
- 17 23. Steerable directional antenna apparatus according to claim 22 wherein the
18 controller is configured to: compare a current link quality of a wireless link
19 between the said antenna and the electromagnetic signal source with the said
20 expected link quality; and select the said steering data portion responsive to a
21 determination that the expected link quality is greater than the said current link
22 quality.
23
- 24 24. Steerable directional antenna apparatus according to any one of claims 19 to
25 23 wherein the said one or more antenna amplifiers configured to adjust a
26 power level of signals to be transmitted or received by the antenna are
27 configured to amplify signals to be transmitted or received by the antenna.
28
- 29 25. A method of generating location specific steering data for a steerable
30 directional antenna, the location specific steering data comprising one or more
31 steering data portions, each of the steering data portions being specific to a
32 respective location, the method comprising: providing the said steerable
33 directional antenna at a location; adjusting a principal communication
34 direction of the antenna to thereby provide a wireless communications link
35 between the antenna and a terrestrial electromagnetic signal source meeting
36 one or more link criteria; and storing the said location together with a steering

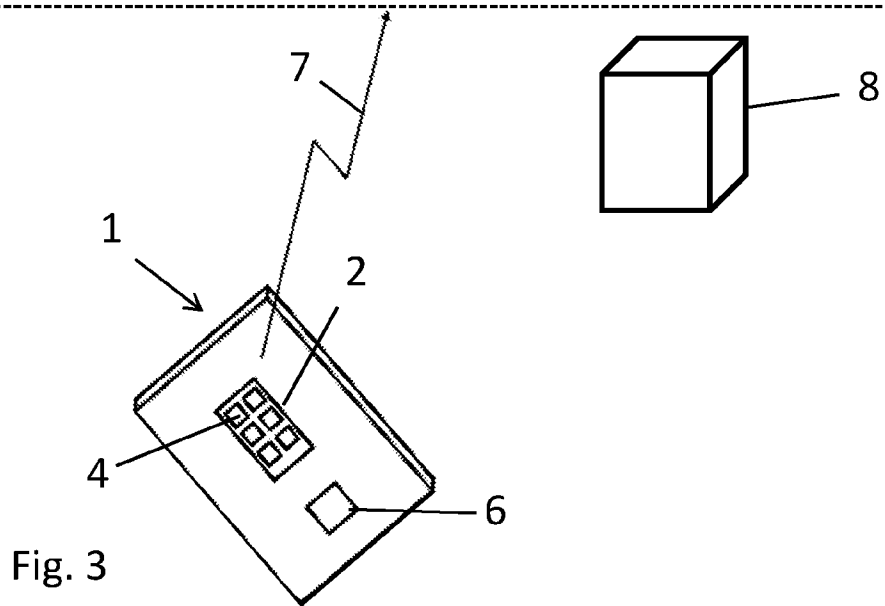
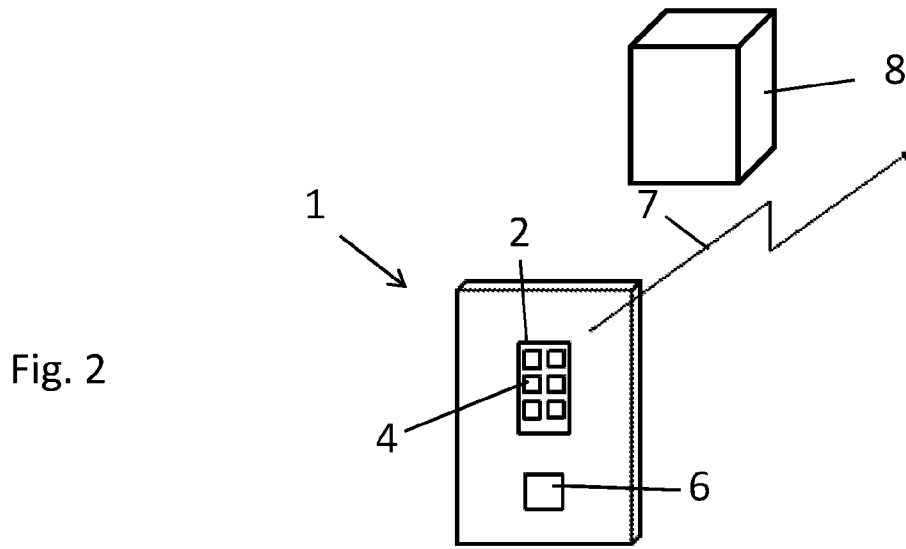
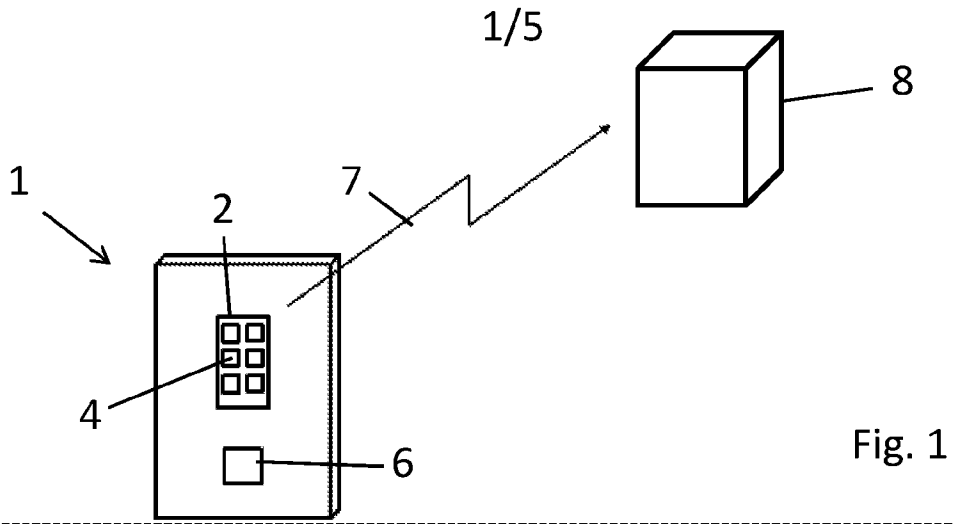
- 1 data portion related to, or derived from, the said adjusted principal
2 communication direction.
3
- 4 26. The method according to claim 25 wherein the said steering data portion
5 comprises any one or more of: an estimated location of the said terrestrial
6 electromagnetic signal source; antenna configuration data representing the
7 said adjusted principal communication direction of the antenna; and data
8 representing the adjusted principal communication direction.
9
- 10 27. The method according to claim 25 or claim 26 further comprising: determining
11 an orientation of the antenna; and storing data representing the said
12 orientation of the antenna together with said steering data portion and
13 location.
14
- 15 28. The method according to any one of claims 25 to 27 further comprising:
16 determining a usage mode of a device comprising the antenna; and storing
17 usage mode data representing the said usage mode together with said
18 steering data portion and location.
19
- 20 29. Steerable directional antenna apparatus comprising: a steerable directional
21 antenna; a memory; and a controller comprising one or more computer
22 processors, the controller being configured to: determine a location of the
23 antenna; adjust a principal communication direction of the antenna to thereby
24 provide a wireless communications link between the antenna and a terrestrial
25 electromagnetic signal source meeting one or more link criteria; and store in
26 the memory the said location together with a steering data portion related to,
27 or derived from, the said adjusted principal communication direction.
28
- 29 30. A non-transitory computer readable medium tangibly embodying computer
30 program code for causing a computer to adjust a principal communication
31 direction of a steerable directional antenna for communicating with a
32 terrestrial electromagnetic signal source by: receiving location specific
33 steering data comprising one or more steering data portions, each of the
34 steering data portions being specific to a respective location; receiving a
35 location of the steerable directional antenna; selecting a steering data portion
36 from the location specific steering data taking into account the received
37 location of the antenna; determining an adjusted principal communication

1 direction of the steerable directional antenna taking into account the said
2 selected steering data portion; and adjusting the principal communication
3 direction of the steerable directional antenna in accordance with the said
4 adjusted principal communication direction,

5
6 wherein the computer program code is further for causing a computer to:
7 provide location specific power level data comprising one or more power level
8 data portions, each of the power level data portions being specific to each of
9 one or more locations, the said power level data portions being indicative of
10 respective power level configurations of one or more antenna amplifiers
11 configured to adjust a power level of signals to be transmitted or received by
12 the antenna; select a power level data portion from the said power level data
13 taking into account the determined location of the antenna; determine a power
14 level configuration of the antenna amplifier(s) taking into account the selected
15 power level data portion; and configure the antenna amplifier(s) in accordance
16 with the said determined power level configuration.

17
18 31. A non-transitory computer readable medium tangibly embodying computer
19 program code for causing a computer to generate location specific steering
20 data for a steerable directional antenna, the location specific steering data
21 comprising one or more steering data portions, each of the steering data
22 portions being specific to a respective location, by: receiving a location of the
23 antenna; adjusting a principal communication direction of the antenna to
24 thereby provide a wireless communications link between the antenna and a
25 terrestrial electromagnetic signal source meeting one or more link criteria; and
26 storing the said location together with a steering data portion related to, or
27 derived from, the said adjusted principal communication direction.

28



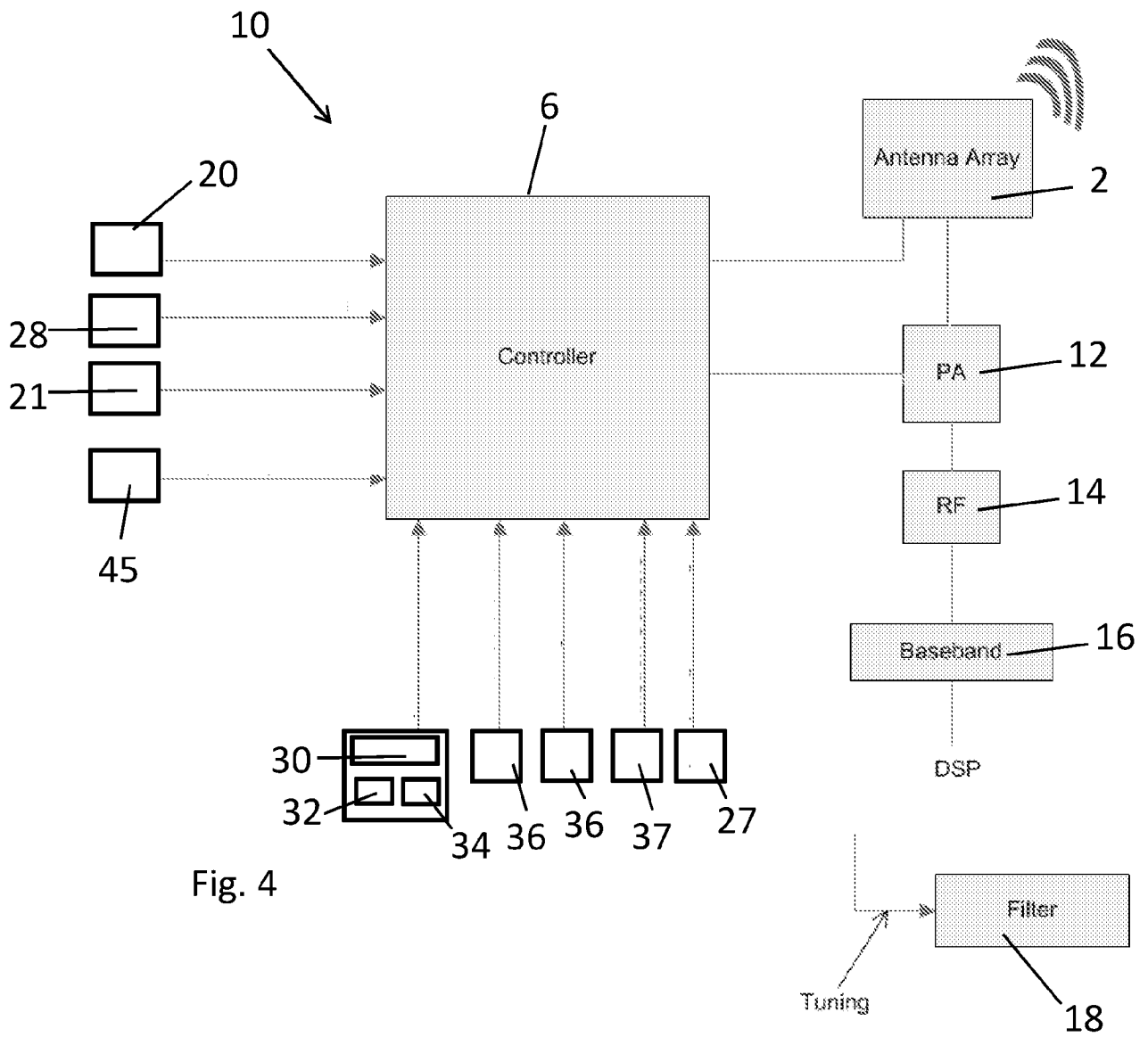


Fig. 4

Location	Steering Data
26 → X1, Y1, Z1	A1, B1, C1 ← 24
26 → X2, Y2, Z2	A2, B2, C2 ← 24
26 → X3, Y3, Z3	A3, B3, C3 ← 24
26 → Xn, Yn, Zn	An, Bn, Cn ← 24

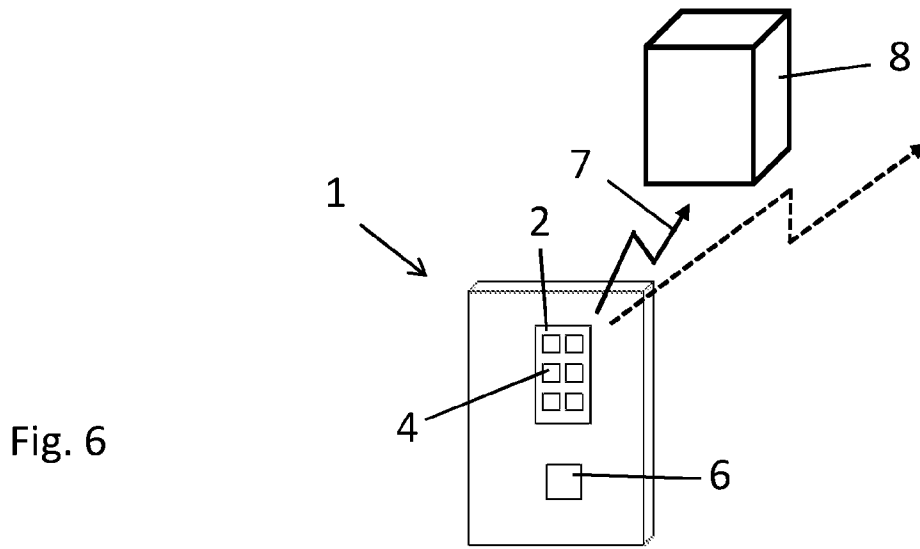


Fig. 6

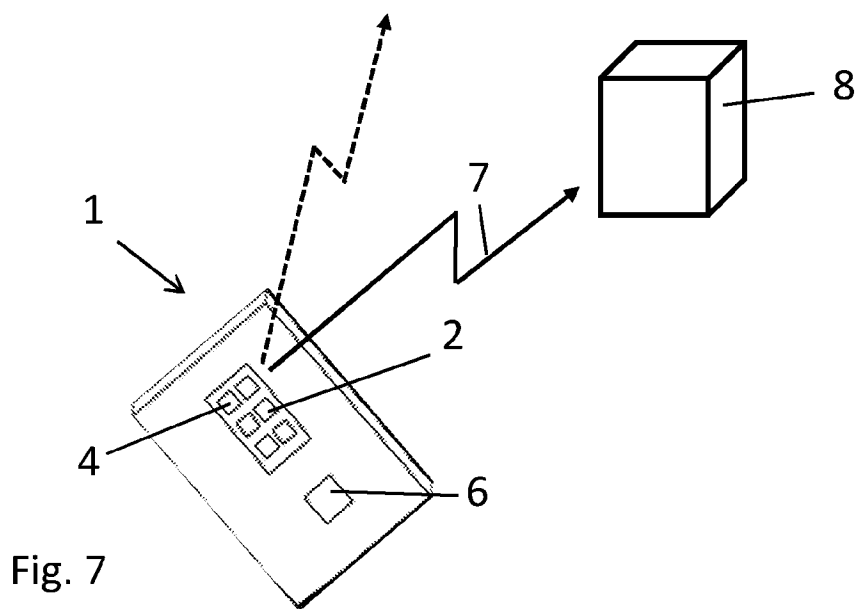
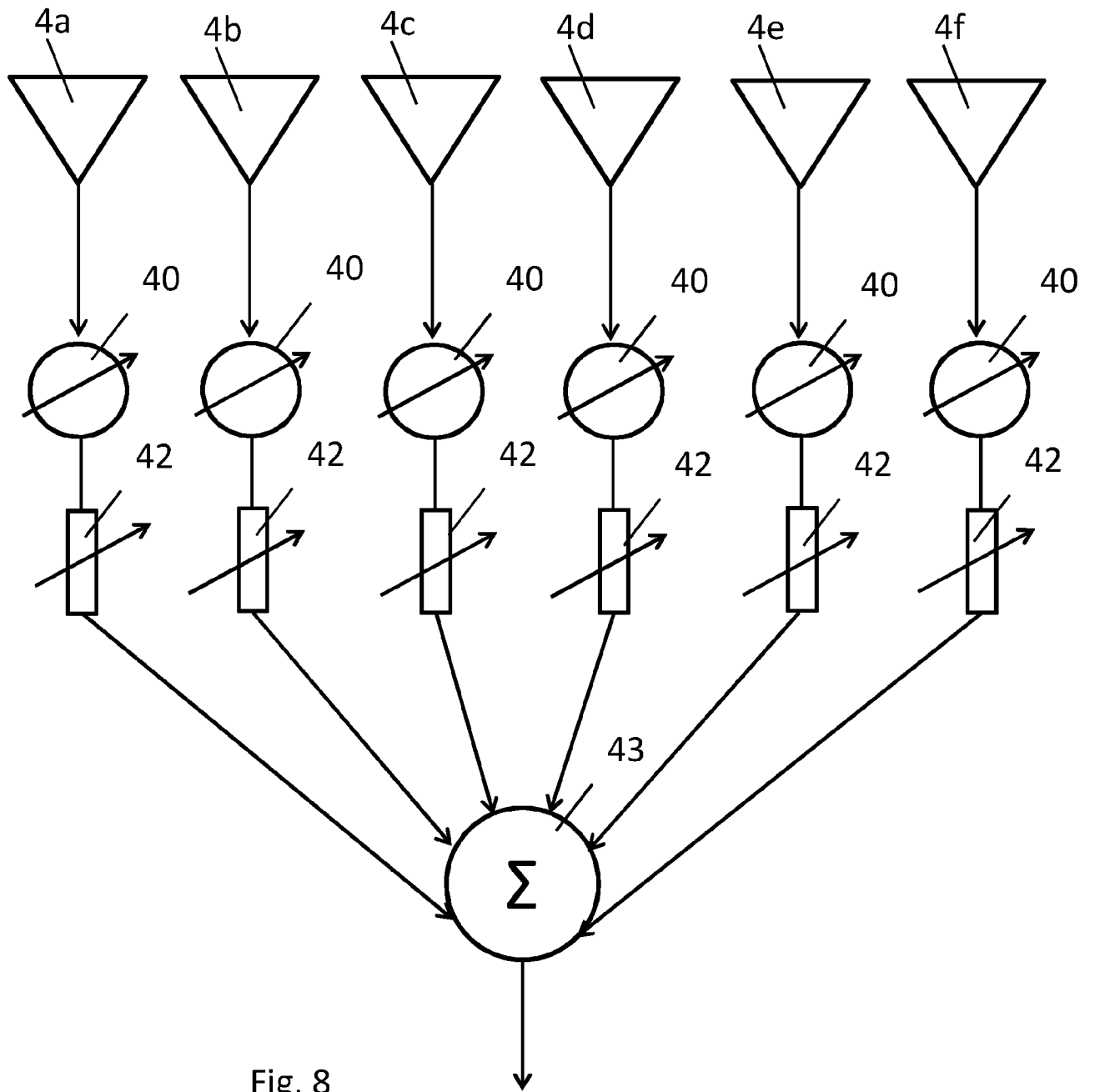


Fig. 7

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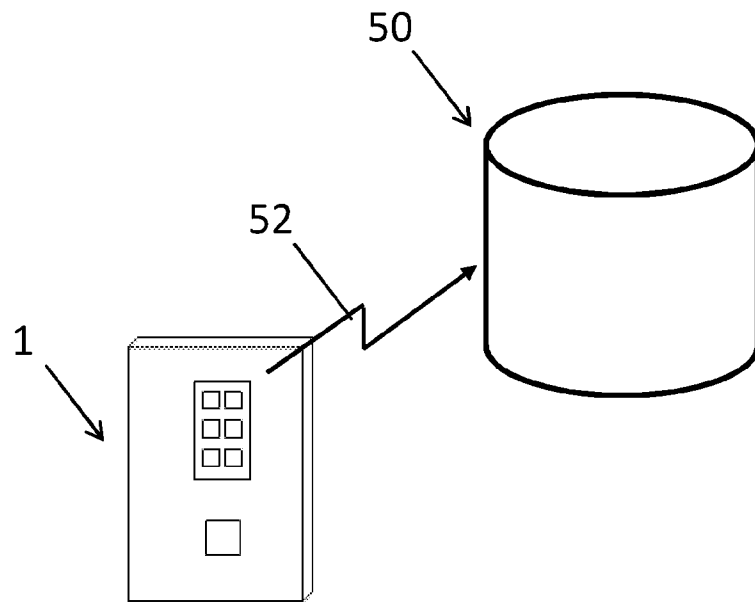


Fig. 9

INTERNATIONAL SEARCH REPORT

International application No PCT/GB2016/053909

A. CLASSIFICATION OF SUBJECT MATTER
 INV. H04B7/0404 G01S1/04 H04B7/06 H04W52/28 H01Q3/26
 ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
 Minimum documentation searched (classification system followed by classification symbols)
 H04B G01S H04W H01Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
 EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2013/231066 A1 (ZANDER OLOF [SE] ET AL) 5 September 2013 (2013-09-05)	25,27, 29,31
Y	paragraph [0006] - paragraph [0010] paragraph [0018] - paragraph [0052] claims 1-16; figures 1-4 -----	1-24,26, 28,30
Y	US 2011/136493 A1 (DIMPFLMAIER RONALD WILLIAM [US] ET AL) 9 June 2011 (2011-06-09)	1-24,26, 28,30
A	paragraph [0035] - paragraph [0069]; claims 1-26; figures 4,6-7 -----	25,27, 29,31
A	US 2013/156080 A1 (CHENG ZHAOJUN [CA] ET AL) 20 June 2013 (2013-06-20) paragraph [0053] - paragraph [0092]; figures 3-11 -----	1-31
	-/--	

Further documents are listed in the continuation of Box C.

See patent family annex.

* Special categories of cited documents :

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"E" earlier application or patent but published on or after the international filing date	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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"O" document referring to an oral disclosure, use, exhibition or other means	"&" document member of the same patent family
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search 8 March 2017	Date of mailing of the international search report 16/03/2017
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Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Kokkinos, Titos
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INTERNATIONAL SEARCH REPORT

International application No PCT/GB2016/053909

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
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A	US 2013/040655 A1 (KEIDAR RON [US]) 14 February 2013 (2013-02-14) paragraph [0007] - paragraph [0019] paragraph [0028] - paragraph [0072] claims 1-68; figures 3-7 -----	1-31
A	US 2013/040682 A1 (CHANG YOUNG-BIN [KR] ET AL) 14 February 2013 (2013-02-14) paragraph [0013] - paragraph [0133]; figures 4-12 -----	1-31
A	US 2005/059388 A1 (HAINES RUSSELL JOHN [GB] ET AL) 17 March 2005 (2005-03-17) paragraph [0009] - paragraph [0034]; claims 1-12; figures 3,4 -----	1-31

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Information on patent family members

International application No

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